WATER & SEWAGE WORKS

WATER SUPPLY SEWAGE DISPOSAL

INDUSTRIAL WASTE TREATMENT

Let's look at the record!

In 1949, Lock Joint Pipe Company supplied or contracted to supply reinforced concrete pressure pipe in 75 cities and towns throughout the western hemisphere. Completion of these contracts requires production of the equivalent of more than 75,000,000 inch diameter feet of pipe varying in size from 12" to 120" and designed for pressures varying from a minimum to better than 200 pounds per square inch.

In 1949, Lock Joint Pipe Company provided pressure pipe for installations from Portland, Maine, to Rio de Janeiro, Brazil—from Denver, Colorado, to Ciudad Trujillo in the Dominican Republic. And if past performance is any criterion, every installation will produce another "satisfied customer."

We will gladly refer you to any or all of the many federal agencies, state or county authorities, private water supply companies and industrial concerns which have installed Lock Joint Pressure Pipe during the last forty years. We are confident that their testimony will prove to be Lock Joint's best salesman.

For over forty years Lock Joint has specialized exclusively in the production and technical improvement of reinforced concrete pipe for water supply and distribution mains, sewers, storm drains, culverts and subaqueous installations.

LOCK JOINT PIPE COMPANY

Est. 1905

P.O. Box 269, East Orange, N. J.

PRESSURE PIPE PLANTS: Wharton, N. J., Turner, Kan., Detroit, Mich.

BRANCH OFFICES: Casper, Wyo. • Cheyenne, Wyo. • Denver, Col. Kansas City, Mo. • Valley Park, Mo. • Chicago, Ill. • Rock Island, Ill. Wichita, Kan. • Kenilworth, N. J. • Hartford, Conn. • Tucumcari, N. Mex. Oklahoma City, Okla. • Tulsa, Okla. • Hato Rey, Puerto Rico

LOCK JOINT Reinforced Concrete PRESSURE PIPE

WATER AND SEWAGE WORKS. Reg. U.S. Patent Off. May, 1950. Volume 97. Number 5. Published monthly by Gillette Publishing Co., at 404 North Wesley Ave., Mount Morris, Ill. Per copy, 25c; except *this issue*, 50 cents. Subscription rate: United States, $2.00 per year; Canada, $2.00 per year; Foreign, $3.00 per year. Entered as second-class matter March 4, 1948, at the post office at Mount Morris, Illinois, under the Act of March 3, 1879. Executive and business offices, 22 W. Maple St., Chicago 10, Illinois. Editorial office, 155 E. 44th St., New York 17, N. Y.

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The greatest improvement in register construction since the invention of the straight reader

NEW *Rockwell-designed* STRAIGHT READING REGISTER ›››››

RECORDING IN EITHER CUBIC FEET OR GALLONS

YOU SET—ALL THESE ADVANTAGES

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STAINLESS STEEL DIAL

HEAT-PROOF WHEELS

SIMPLIFIED RESETTING TO ZERO.

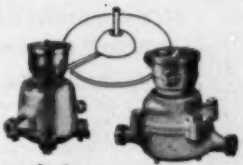
LARGE RED TEST HAND

Now available on new meters or for parts replacement.

PITTSBURGH EQUITABLE WATER METERS

Pittsburgh Equitable Meter Division

ROCKWELL MANUFACTURING COMPANY



Pittsburgh 8, Pa.

Atlanta Boston Chicago Columbus Houston Kansas City Los Angeles New York Pittsburgh San Francisco Seattle Tulsa

DON'T get caught with your stocks down. Always keep a good supply of Sanitation HTH on hand.

Emergencies are inevitable. In times of floods, broken mains, power failures, chlorinator breakdowns and other unforeseen developments, nothing is as reassuring as plenty of HTH – *in your stock room.* HTH is also handy for those everyday jobs – regular chlorination, sterilizing reservoirs, new water mains, water tanks, or filters.

Sanitation HTH is easy to use and store. It is dry, free-flowing and *always* provides a minimum of 70% available chlorine. Play safe – replenish your stocks of HTH today. For the many uses of HTH write today for your copy of "Hypo-Chlorination of Water." Mathieson Chemical Corporation, Mathieson Building, Baltimore 3, Maryland.

Sanitation HTH is available in cases of nine handy 5-lb. cans and in 100-lb. drums.

Mathieson
CHEMICALS

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SERVING INDUSTRY, AGRICULTURE AND PUBLIC HEALTH

WATER & SEWAGE WORKS

WATER SUPPLY—SEWAGE DISPOSAL—INDUSTRIAL WASTE TREATMENT

E. S. GILLETTE, Publisher

L. H. ENSLOW, Editor

"Cool, Clear Water!"

(On This Month's Cover)

In this day of water shortages and polluted streams one can but think—Blessed is the country that can boast of scenes like this; and, of such an abundance of cool clean waters. Such is the case in the Pacific Northwest where the Skykomish rushes from the lofty Cascades to join the Snohomisch near Everett, Wash.

This picture was made by that past-master photographer of the Northwest—Roy Atkeson of Portland, Oregon.

COMING!

Modernization of a Filtration Plant—and Some Results Therefrom

In the subject of an article which describes the adaptation of some of the most modern filter plant equipment and methods of raw-water preparation, filtration and chlorination. This article can be calculated to create the envy of progressive operators who may not have been able to secure up-to-date equipment, as has the author of this article. Planned for this issue, we regret the necessity of holding it for our June issue. The fortunate author is—

F. R. GEORGIA, Supervisor,
Cornell Univ. Filter Plant & Water System, Ithaca, N.Y.

Sludge Drying—Sand Beds vs. Shallow Lagoons

An interesting study made by the Los Angeles County Sanitary Distr. reveals some little suspected aspects and economics of dewatering and drying of digested sludges in shallow lagoon type beds, without underdrains, in comparison with orthodox underdrained sand beds. The conclusions reached are eye-opening in respect to the overall costs of sludge dewatering by the two methods. This paper comes from—

A. M. RAWN and W. F. GARBER,
Los Angeles County Sanitation Districts.

Sodium Fluosilicate in Fluoridation

Amongst the earliest to adopt fluoridation of its water supply was Sheboygan, Wis. In the interim Sodium Silicofluoride has been suggested as an alternate to Sodium Fluoride, at a considerable saving in cost of the chemical for equal amounts of fluoride ion. Sheboygan has now completed a year period with the Silicofluoride. The methods employed and what has been learned in the trial period, and the economy, is to be reported in our next issue by—

JEROME C. ZUFELT,
Supt. of Water, Sheboygan, Wis.

Improved Sulphate Determination

The procedure in "Standard Methods" for determinination of the Sulphate SO4 ion has by the Benzidine Hydrochloride Method two serious limitations. These have been overcome in a modified procedure described in detail in this article. The new procedure is not only applicable over a wider and more useful range, but is more accurate and requires no determination of a "blank." "Sulphate Determination with a Modified Benzidine Hydrochloide Method" is the contribution of—

R. S. INGOLS and J. W. McCONNELL,
Ga. Inst. of Technology, Atlanta, Ga.

Settling Tank Design

Is discussed by Prof. F. Popel of Stuttgart, Germany, in an illuminating article which appeared in "Gesundheits Ingenieur." We have asked C. E. Keefer, Deputy Sewerage Engr., of Baltimore, to prepare a translation of this important article for publication in an early issue. To this Prof. Popel is adding more recent disclosures than those appearing in the original article, plus a useful design nomograph.

Managing Editor

GEORGE E. SYMONS, PH.D.

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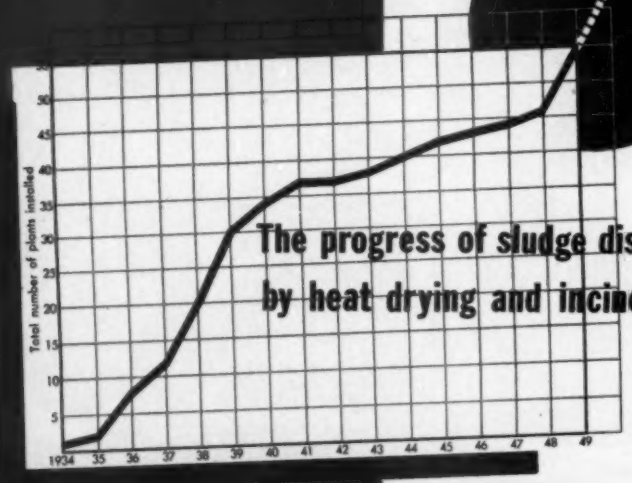
NICHOLS

RECORD OF CONTINUOUS PROGRESS



The progress of sludge disposal by heat drying and incineration

ANN ARBOR, MICH. . . . April 1949

BRIDGEPORT, CONN. East Plant May 1949

AKRON, OHIO . . . . May 1949

PROVIDENCE, R. I. . . . June 1949

BRIDGEPORT, CONN. West Plant Nov. 1949

These cities made two important decisions during 1949 in solving their sewage sludge disposal problems, by specifying heat drying and incineration as the best methods and Nichols Multiple Hearth Incinerators as the best means.

WHY?

Low initial cost · Compact disposal plant
Economy of operation

NICHOLS — *the foremost name in incineration.*

NICHOLS ENGINEERING & RESEARCH CORPORATION

, NEW YORK 5, N. Y.

• 1477 Sherbrooke St. West, Montreal 25, Canada

WE ARE LOOKING FORWARD to seeing you at the A.W.W.A. Convention to be held in Philadelphia from May 21 to 26. A most friendly welcome awaits you, and we hope that many of you will take the opportunity to get better acquainted with our products by visiting our plant in Florence, N. J., near Philadelphia.

At the Convention, our products will be on display in Booths 217 and 219. Come and see for yourself how simplicity of design and ease of replacement make the Modernized Mathews Hydrant a vital link in the fire fighting system of every modern, safety-minded community.

MATHEWS HYDRANTS

***Made by* R. D. WOOD COMPANY**

Public Ledger Bldg., Independence Square, Phila. 5, Pa.

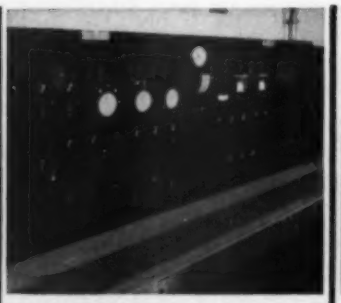
Manufacturers of "Sand-Spun" Pipe (centrifugally cast in sand molds) and R. D. Wood Gate Valves

Stamford invests in

Sewage treatment and incineration are combined into one operating unit at Stamford, Conn. The plant uses the elutriation process to condition sludge. The effluent is post-chlorinated and sludge is flash dried for sale as a soil conditioner.

General Electric motors and control used throughout the plant keep running expenses low.

At this outdoor G-E unit substation, high voltage is dropped to utilization voltage for distribution to G-E motors and control throughout the plant. G-E standardized unit substations are completely factory-assembled, ready-to-install units.



One of the nerve centers of the Stamford plant, this G-E Cabinetrol control installation centralizes low-voltage control of motors, lighting, and other auxiliary equipment. Such installations conserve space and save steps; make for more efficient operation.

These G-E vertical motors drive centrifugal pumps which pick up sewage after it passes through bar screens. The control above the first motor automatically selects the pump or pumps needed to handle the flow. Five motors—one 20-hp, one 40-hp, and three 75-hp—are used.

GENERAL ELECTRIC

666-57

CLEAN WATERS

Modern G-E Equipped Combination Wastes Plant Economically Serves City of 70,000

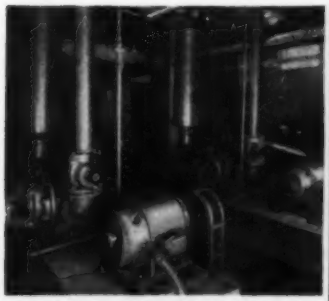
Before 1944, most of Stamford Connecticut's sewage had to run through its treatment plant quickly or by-pass it entirely. This created an unhealthful condition in Stamford Harbor and Long Island Sound. Today, *Stamford's waters are clean.*

Finding itself in the same situation as many other cities where the war brought increases in industrial activity and population, Stamford solved its sanitation problem by rebuilding its sewage treatment and incineration plants to combine them into one operating unit.

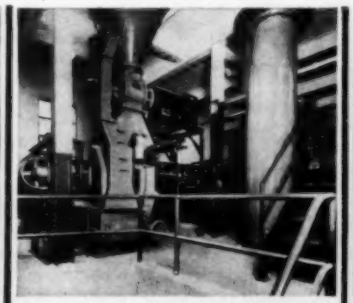
This investment in *clean waters* is returning large dividends in the form of better health, cleaner beaches, and higher community standing. What's more: the plant operator says the power cost of the new plant is less than the old one, thanks to modern processes and equipment recommended by the consulting engineer and General Electric.

General Electric can help your community get that new or improved sewage treatment plant by giving engineering assistance to help you and your consultant —*first* in helping formulate electrical plans and *second* in building public support with the full-color sound movie *Clean Waters*.

Contact your General Electric office early in the planning stage. The nearest G-E office is listed in your local classified 'phone directory. *Apparatus Dept., General Electric Co., Schenectady 5, N. Y.*



The Tri-Clad motors shown above are V-belted to vacuum pumps used in the sludge dewatering process. Sludge is pumped from the elutriation tanks into vacuum filters for de-watering. Motors are 15 hp, 1800 rpm, and operate on 208-volts, 3-phase, 60-cycle a-c.



From the vacuum filter, sludge is conveyed from the sludge drying and weighing equipment. Drying and weighing equipment is at left, a dry divider at right rear. View shows one of several G-E motors used throughout the process.

Dry sludge is driven by means of screw feeders into garbage and refuse incinerators when required; normally, however, it is bagged and sold. Tri-Clad® special-purpose, open, gear-motors, mounted on the frame at upper right, chain-drive the conveyors.

GE SEWAGE-PLANT

for Safety, Surety and Savings

...OPERATE DISTANT VALVES

by LIMITORQUE REMOTE CONTROL

The important safety factor afforded by *LimiTorque Remote Control* cannot be overstressed, because men do *not* have to go to high, low, dangerous or inaccessible locations to open and close valves. Further, *LimiTorque* prevents damage to seats, discs, stems, etc., because it *"automatically" shuts-off the power,* should an obstruction in closing occur.

Think of the savings effected in time and money by eliminating men going from one valve to another (many of which are at distant locations)—not to mention the time required to shut or open each valve. *LimiTorque Remote Control* not only prevents this waste, but enables one man to merely *"push buttons"* and actually see on a panelboard whether the valves are open or closed.

Various *LimiTorques* are available for different requirements on all types of valves (globe, gate, butterfly, plug, etc.)—and, too, *LimiTorques* may be supplied for actuation by any power source, such as electricity, steam, water, gas, oil or air.

Thousands of *LimiTorques* are in use throughout the world, on land and sea. Be convinced; send for our 96-page catalog, L-48, and please use your Business Letterhead when requesting it.

Philadelphia Gear Works, INC.

ERIE AVE. AND G ST., PHILADELPHIA 34, PA.
NEW YORK • PITTSBURGH • CHICAGO • HOUSTON
IN CANADA: WILLIAM AND J. G. GREEY LIMITED, TORONTO

Industrial Gears and Speed Reducers
LimiTorque Valve Controls

Lithographed on stone by James E. Allen

U.S. cast iron PIPE

FOR WATER AND GAS AND INDUSTRIAL SERVICE

Cast iron pipe is tough, husky, but not exactly handsome. What it lacks in eye appeal it makes up for in dependable quality. To see that our product's reputation for quality is lived up to—and to strive for still higher quality—this Company has made substantial investments in facilities for *quality control* and for *research and development.* The recently completed Research Laboratory and Developmental Foundry at Burlington is an important contribution to a long-range program of process and product development. **United States Pipe and Foundry Company, General Offices: Burlington, N. J. Plants and Sales Offices Throughout U. S. A.**

Pardon our Latin, gentlemen, but–"Caveat Emptor!"

"LET THE BUYER BEWARE" was a good piece of early Roman advice.

It was still good when we first met you—and introduced you to the General Electric Disposall.®

You were wary, rightfully so, of a kitchen appliance that shreds all food waste into tiny particles, and flushes it down the drain and into the sewer.

You agreed that any method that would completely eliminate garbage was a good thing for the community. But you wanted proof that the Disposall method would not result in sewage stoppages or in any way impair the efficient operation of your sewage system.

You wanted evidence that it was safe for the home-owner—practical and economical for the community.

We believe that we have answered every question to your satisfaction, gentlemen. The Disposall method

has been accepted throughout the land. Disposalls are in everyday use in thousands of homes—in cities large and small.

When necessary, farsighted sanitation officials have seen fit to revise out-dated sanitation codes to permit the use of this revolutionary appliance in the homes of their communities.

Doubtless, there are other food-waste shredders that will be able to convince you of their efficiency and economy. Appliances that will meet the strictest examination.

But, because the Disposall is the pioneer in the field of scientific garbage elimination—and has proved itself in the laboratory and in countless homes—we believe you will be interested in reading the specifications below. They are the very specifications used in the development and perfection of the General Electric Disposall.

They may be of use to you in drawing up your own list of requirements.

GENERAL ELECTRIC'S SPECIFICATIONS FOR ITS FOOD-WASTE SHREDDER— THE DISPOSALL

1. *The Disposall has a flow interlock that permits operation with cold water only.*

This requirement is necessary because experience has shown that only with cold water will greases become congealed within the cylinder. With congealed grease broken up into small particles, mixed with food waste and carried off through the drain, there can be little tendency for greases to adhere to the walls of the pipe.

2. *The discharge from the Disposall remains in a fluid state. The correct relationship between the amount of food waste and tap water is maintained by controlled shredding.*

This equalization of water and food waste permits the ready flow of effluent through traps, drain, or soil lines in a manner to prevent clogging.

3. *The Disposall shreds food waste to a uniform size, to meet the following requirements: 100% shall pass a ½-inch screen. At least 90% shall pass a ¼-inch screen. Not more than 5% shall pass a #10 sieve.*

(Screens should be the United States standard, and weight should be taken on a dry basis.)

In other words, the particles of shredded food waste are of the correct size, to permit effective sewage clarification and sludge digestion at the treatment plant.

4. *The food-waste shredder is self-scouring, with no fouling surfaces.*

This feature prevents objectionable odors; keeps the unit clean as a whistle.

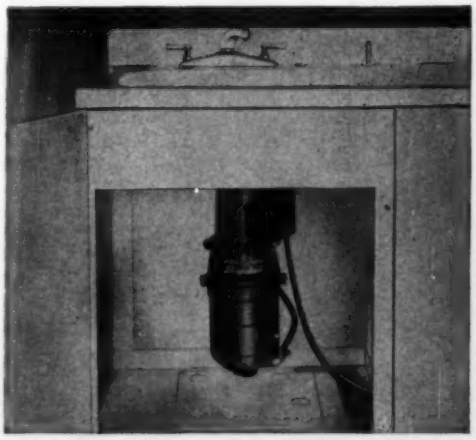
5. *The food-waste shredder provides maximum protection against electrical or mechanical hazards.*

As a safety measure, the shredding compartment is inaccessible during operation.

6. *The food-waste shredder is designed for connection to the plumbing, in accordance with the local plumbing code, and should be free from any cross connection.*

This regulation eliminates any makeshift, homemade hook-ups, and permits the proper operation from sink to sewage treatment plant.

For further information about the Disposall method, simply write to Department W & W 505, General Electric Company, Bridgeport 2, Connecticut.



The General Electric Disposall is easily installed in almost any sink. Here it is shown installed in our electric sink. Food waste is scraped into drain opening, and safety cover is placed in position. The cold-water tap is then turned on, starting the Disposall operation. Food waste is shredded and flushed away automatically.

P. S. Thousands of Disposalls are operating successfully on private septic tank systems.

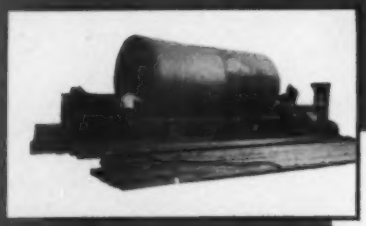
Disposall

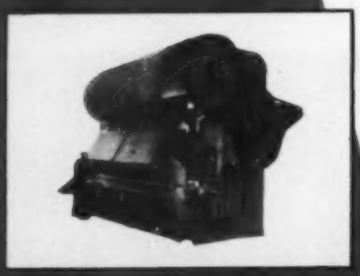
CONVERTS FOOD WASTE TO SEWAGE—ELIMINATES "GARBAGE"

GENERAL ELECTRIC

FACTS ABOUT STEEL PLATE CONSTRUCTION

that Engineers often need but Fabricators seldom publish





Engineers purchasing steel plate construction often ask themselves the question: "Has this supplier the capacity and the equipment to do the job according to specifications and on time?"

Usually, they are offered little definite information that would help them make a decision. Recently, however, Posey Iron published a 12-page reference bulletin giving details about Posey capacity and equipment.

Located in Lancaster, Pa. . . . a railroad and highway center . . . the modern plants of the Posey Iron Works cover an area of 16½ acres under roof. Manufacturing advantages provided by this extensive, modernized plant often permit the Posey Iron Works to meet both "special" and standard requirements with greater skill . . . greater speed . . . and greater economy. Materials are carefully selected to meet specifications and liberal allowance is always made for safety factors.

To learn of facilities that may lower your steel plate construction costs, write today for your free copy of the Posey Production Facilities Bulletin.

Established 1910

POSEY IRON WORKS, INC.

ELEVATED TANKS
STACKS • TANKS
STORAGE TANKS
GENERAL STEEL
PLATE FABRICATION

STEEL PLATE DIVISION
formerly LANCASTER IRON WORKS, INC.

LANCASTER, PA.

DIVISIONS
BRICK MACHINERY
FOUNDRY • INDUSTRIAL
HEATING • IROQUOIS
SHIPBUILDING
STEEL PLATE

ADVANCED BADGER ENGINEERING brings you the DOVETAIL THRUST ROLLER INSERT

Because BADGER METER engineers refuse to "rest on their laurels," they continue to maintain the world's highest standards of water meter performance. This new Badger Dovetail Thrust Roller Insert is typical of the constructive research and precision achievements in progress continually at BADGER.

What does this Badger Dovetail Thrust Roller Insert accomplish? It saves important time and replacement costs . . . because, with this removable plate set into the chamber wall, the thrust roller (in the disc) rolls against the *insert* only . . . thus preventing wear directly in the chamber thrust roller *slot* (which would damage the chamber itself). If wear occurs on the *insert*, that is no problem, because it can be replaced easily, at a small fraction of the cost and time required to replace an entire new chamber.

In addition, advanced Badger engineering of this unique insert assures you of accurate metering through unimpaired freedom of disc movement, because:

1 Both halves of chamber remain stronger, since this insert requires only a short slot (about 77% shorter slot milled in chamber wall).

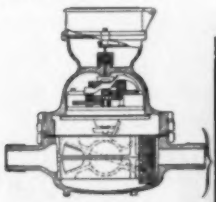
2 Precision design and machining permit insert to be held accurately and securely in place between the two halves of the chamber.

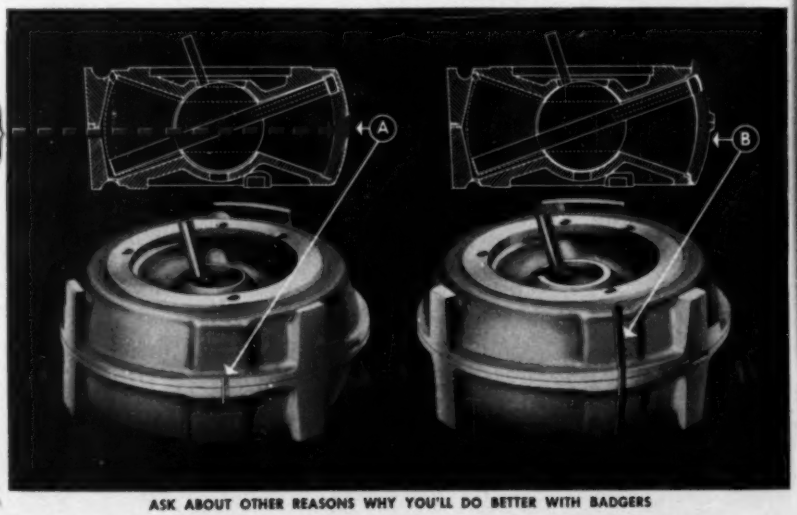
3 The precision dovetail design prevents insert from shifting or moving.

4 The increased radius of the insert along the area nearest the disc, assures ample clearance always between disc and insert, even in the extreme allowable vertical shift.

Only in BADGER METERS will you find this advanced type of engineering and precision production which has convinced waterworks men in over 5000 communities that "BADGERS are the best buy in meters."

. . . another **"BADGER-*First*"**





A New style: 77% shorter slot...adds strength to chamber-halves; prevents distortion. Dovetail prevents shifting of insert. Increased radius assures freedom of disc movement. No wear on chamber; wear confined to the easily replaceable insert.

B Old style: This full length slot weakened the chamber-halves . . . made them subject to distortion.

ASK ABOUT OTHER REASONS WHY YOU'LL DO BETTER WITH BADGERS

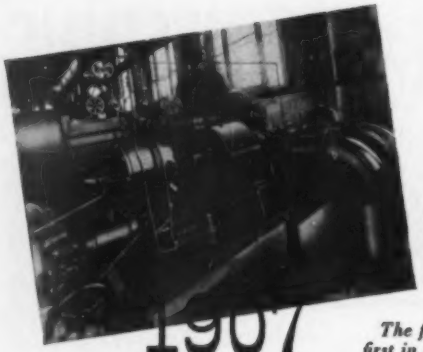
BADGER METER MFG. CO., Milwaukee 10, Wis.

Branch Offices: New York City • Philadelphia • Worcester, Mass. • Savannah, Ga. • Cincinnati • Chicago • Kansas City Waco, Texas • Salt Lake City, Utah • Guthrie, Okla. • Seattle, Wash. • Los Angeles

BADGER *Water* METERS

"MEASURING THE WATER OF THE WORLD"

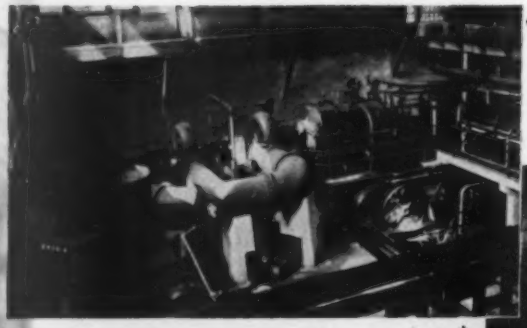
First FOR ACCURACY • LOW-COST MAINTENANCE • DURABILITY • SENSITIVITY



Philadelphia's first pumping engine, installed in the year 1000 (not a De Laval).

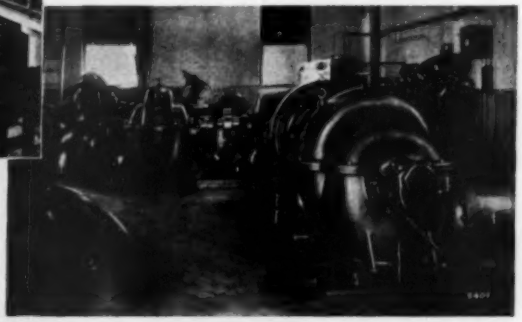
The first centrifugal waterworks pump in Philadelphia and one of the very first in the entire nation.

The city of Philadelphia was one of the first to replace the ponderous pumping engines of the nineteenth century with compact, highly efficient turbine-driven centrifugal pumps. The first of the centrifugal units to be used by the city of Philadelphia was a De Laval 2½ mgd turbine-driven unit installed at the Torresdale Station in the year 1907.



Queen Lane Pumping Station

In the year 1919 the City of Philadelphia broke all records for pumping capacity by equipping the Queen Lane Pumping Station with four De Laval turbine-driven units each having a capacity of 40 mgd against 279′ head.



Roxboro Booster Station

One De Laval 17 mgd and two De Laval 20 mgd motor-driven pumps are used in this station.

Shawmont Pumping Station

These two De Laval 2,095 hp motor-driven, centrifugal pumps have a capacity of 25 mgd each against 405′ head.

Belmont Pumping Station

Three De Laval motor-driven centrifugal pumps designed to deliver 25 mgd against 334′ head.

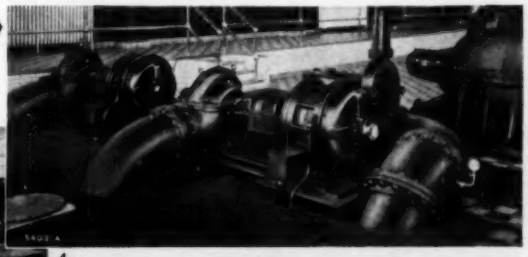
to Philadelphia

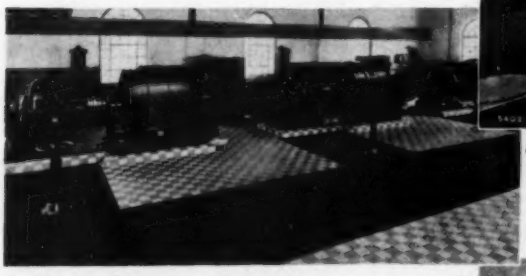
ONE OF THE MANY AMERICAN CITIES, LARGE AND SMALL, SERVED BY DE LAVAL WATER WORKS PUMPS.

A cordial reception awaits you at De Laval Booths No. 107-109 American Water Works Convention, Philadelphia, where we look forward to renewing our many friendships among the members of the water works profession.

Torresdale Pumping Station

Two De Laval 8 mgd, 75 hp motor-driven pumps are used here for wash water service.



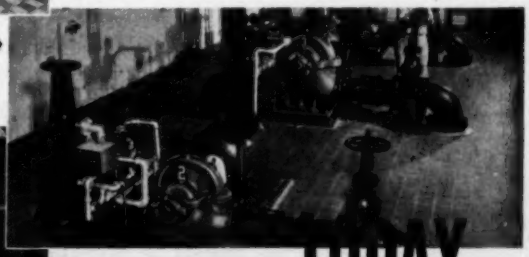


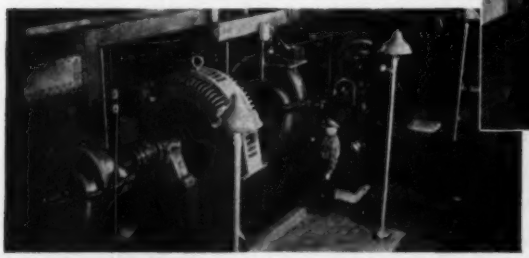
East Park Booster Station

Each of the three De Laval pumps in this neat station is rated at 25 mgd against 149′ head and is driven by a 745 hp synchronous motor.

Fox Chase Booster Station

Three of four De Laval pumping units at Fox Chase.





Lardner's Point

Four De Laval tandem, motor-driven units each consisting of a 2000 hp motor connected at one end to a 40 mgd, 246′ head pump and at the other end to a 30 mgd, 85′ head pump.

TODAY

WRITE DEPT. 10-11-WS.

DE LAVAL STEAM TURBINE COMPANY

Trenton 2, N. J.

TURBINES • HELICAL GEARS • CENTRIFUGAL BLOWERS AND COMPRESSORS
CENTRIFUGAL PUMPS • WORM GEAR SPEED REDUCERS • IMO OIL PUMPS

WW-11

Without bursting strength—or, for that matter—without all of the strength factors listed opposite—no pipe laid 100 years ago in *city streets* would be in service today. But, in spite of the evolution of traffic from horse-drawn vehicles to heavy trucks and buses—and today's vast complexity of subway and underground utility services—cast iron gas and water mains, laid over a century ago, are serving in the streets of more than 30 cities in the United States and Canada.

Such service records prove that cast iron pipe combines all the strength factors of long life with ample margins of safety. No pipe that is provably deficient in any of these strength factors should ever be laid in city streets. Cast Iron Pipe Research Association, Thos. F. Wolfe, Engineer, 122 So. Michigan Ave., Chicago 3.

CAST IRON PIPE

Strength factors of Long Life!

No pipe that is provably deficient in any of these strength factors should ever be laid in city streets

BURSTING STRENGTH

In full length bursting tests standard 6-inch cast iron pipe withstands more than 2500 lbs. per square inch internal hydrostatic pressure, which proves ample ability to resist water-hammer or unusual working pressures.

SHOCK STRENGTH

The toughness of cast iron pipe which enables it to withstand impact and traffic shocks, as well as the hazards in handling, is demonstrated by the Impact Test. While under hydrostatic pressure and the heavy blows from a 50 pound hammer, standard 6-inch cast iron pipe does not crack until the hammer is dropped 6 times *on the same spot* from progressively increased heights of 6 inches.

CRUSHING STRENGTH

The ability of cast iron pipe to withstand external loads imposed by heavy fill and unusual traffic loads is proved by the Ring Compression Test. Standard 6-inch cast iron pipe withstands a crushing weight of more than 14,000 lbs. per foot.

BEAM STRENGTH

When cast iron pipe is subjected to beam stress caused by soil settlement, or disturbance of soil by other utilities, or resting on an obstruction, tests prove that standard 6-inch cast iron pipe in 10-foot span sustains a load of 15,000 lbs.

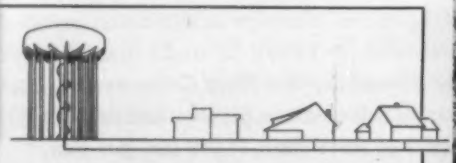
SERVES FOR CENTURIES

how a city benefits *from a*

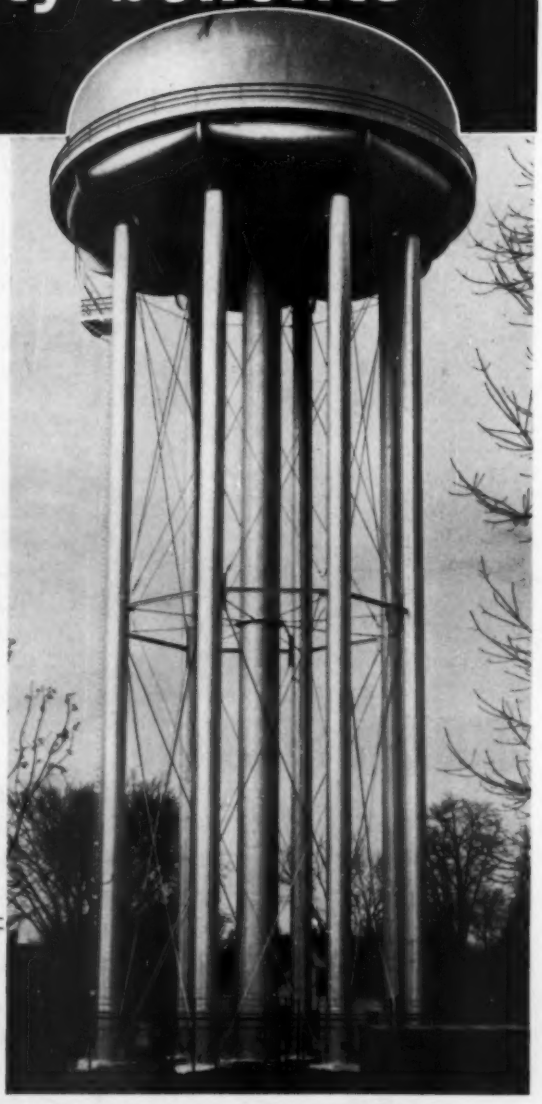
Horton Elevated Tank

The *specific* advantages gained from an elevated water tank will, of course, vary somewhat from city to city. You can be certain though, that — on the basis of actual reports — Horton elevated tanks are determining factors in obtaining the following benefits for cities:

- More uniform pressures throughout the distribution system
- More dependable supply of water for fire protection.
- Lower insurance rating for the city.
- Maintenance of pressure during temporary power failures.
- Provision for pumping during off-peak periods when power rates are most favorable.



The above sketch shows how a Horton elevated tank provides gravity water pressure to a community. Notice how the water is stored above the houses—and that its flow depends only on unfailing force of gravity. Horton radial-cone bottom tanks like this are available in capacities from 500,000 to 3,000,000 gallons. We also build ellipsoidal-bottom elevated tanks in standard capacities from 15,000 to 500,000 gals. Write our nearest office for details.

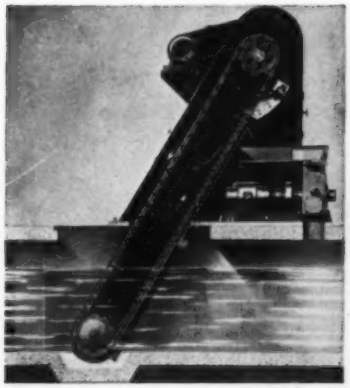


Illustrated above is a typical Horton radial-cone bottom elevated tank, installed for the City of Rock Island, Illinois. This attractive structure, 124-ft. to bottom, has a capacity of 500,000 gallons.

CHICAGO BRIDGE & IRON COMPANY

Atlanta 3	2181 Healey Building	Detroit 26	1551 Lafayette Building	Philadelphia 3	1644—1708 Walnut Street Building
Birmingham 1	1586 North Fiftieth Street	Houston 2	2115 National Standard Building	Salt Lake City 4	550 West 17th South Street
Boston 10	1040—201 Devonshire Street	Havana	402 Abreu Building	San Francisco	1283—22 Battery Street Building
Chicago 4	2198 McCormick Building	Los Angeles 17	1555 General Petroleum Building	Seattle 1	1350 Henry Building
Cleveland 15	2262 Guildhall Building	New York 6	3390—165 Broadway Building	Tulsa 3	1646 Hunt Building

Plants in BIRMINGHAM, CHICAGO, SALT LAKE CITY and GREENVILLE, PENNSYLVANIA



for the "BIGS" and the "smalls" REX provides *proved* equipment

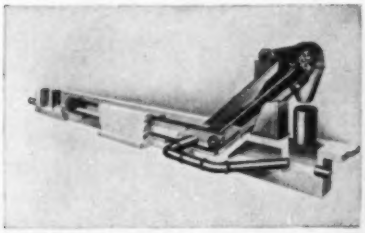
Large plant or small . . . primary or complete treatment . . . domestic or industrial waste, Rex Sanitation and Process Equipment is right for all.

Rex engineers consider the requirements of the small plant as well as the large . . . provide equipment that exactly suits the requirements. Equipment for the smaller plants is not just "scaled down" but is designed and built for the specific problems encountered. Conversely, large plant units are built for the job they must do.

Too, Rex answers the problem of the overloaded plant . . . offers equipment that can frequently expand existing capacities without enlargement of plant size.

In any plant, Rex provides unequaled efficiency . . . capacity . . . sets the standards for economical, long-life operation. Specially trained Rex sanitation engineers will be happy to assist you with your individual problems. For complete information, write for your copy of Bulletin 48-41. Chain Belt Company, 1610 West Bruce Street, Milwaukee 4, Wisconsin.

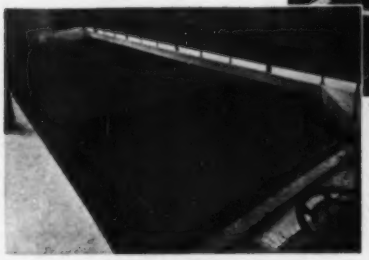
REX MECHANICALLY CLEANED BAR SCREENS AND TRITURATORS are neat, streamlined units that provide an efficient means of removing large solids from liquids and reducing them in size. Reduced material is returned into the sewage flow for quick and efficient handling in settling tanks and digesters.



REX GRIT EQUIPMENT with its exclusive recirculating principle, effectively separates and removes inorganic solids from liquids. No grit washer is required. Rugged construction assures long, economical service.

REX CONVEYOR SLUDGE COLLECTORS combine the well-known advantages of the rectangular settling tank with a rugged and efficient form of sludge removal mechanism. Whether handling primary sludge or light flocculent solids, their performance is efficient and economical.

REX SLO-MIXERS AND FLASH MIXERS assure rapid disbursement of chemical throughout the liquid, followed by a gentle, multi-stage slow mixing for optimum floc formation. Rex Slo-Mixers eliminate short-circuiting and effect savings in chemicals.



REX VERTI-FLO delivers a highly clarified effluent with an extremely short detention period. It provides maximum tank capacity for any desired tank size and maximum practical weir length. The combination of large weir length and low vertical velocities assures a clearer effluent, for greater capacity at minimum cost.

REX TOW-BRO SLUDGE COLLECTORS assure accurate control of sludge removal over a wide range of withdrawal rates through their exclusive suction principle. Sludge is removed immediately on contact instead of the usual plowing or scraping. Greater sludge concentration, greater operating flexibility, and a clearer effluent are a few of the many advantages.

CHAIN BELT REX COMPANY

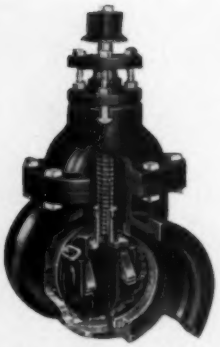
SANITATION EQUIPMENT

IOWA products

meet your most exacting specification

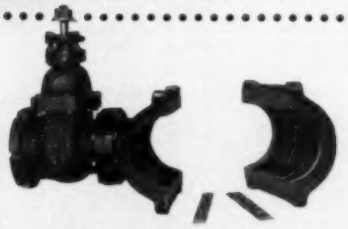
Superiority of Design, Workmanship, and Materials Assures Efficient Trouble Free Operation . . .

In every job



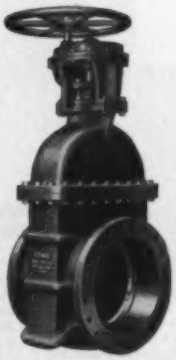
IOWA GATE VALVES—Simple, rugged construction, fully bronze mounted. Parallel seat, double disc type with independent solid bronze wedges and stem nut. Trouble free service assured.

IOWA CHECK VALVES—Balanced swing type, bronze trimmed throughout. Equipped with stainless steel hinge pin. Furnished with rubber or leather faced disc if desired. For installation in either horizontal or vertical pipe lines. Extremely low loss of head.



IOWA TAPPING SLEEVES and VALVES—Sturdily built, easy to assemble and center on pipe. All bolted type with lead strips for tight sleeve connections. Extra long body sleeves with heavy flanges amply protect the cut. All sizes available.

IOWA FIRE HYDRANTS—Latest Corey type conforming to AWWA specifications. Will not geyser when standpipe is broken. Unique design provides unrestricted water flow with extreme low loss of head.



IOWA SQUARE BOTTOM VALVES—Specially designed for throttling service in filter wash and pump discharge lines. Square bottom features can be built into gate valves of any pressure ratings.

IOWA HYDRAULIC VALVES—Superiority of design matched with sturdy construction meets severe, continuous filter service requirements. Available with either iron, brass lined or brass tubing cylinders.

IOWA SLUICE GATES—Heavy cast iron construction, fully bronze mounted. Provided with solid bronze adjustable wedges. Suitable for seating and unseating pressures. Wide range of sizes.

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DANVILLE, VA.

Water Filtration Plant

(COMPLETED IN 1949)

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Engineers
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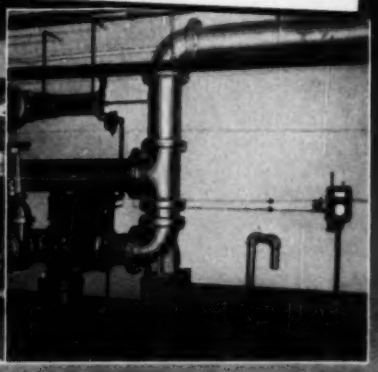
V. B. HIGGINS CO.
Contractors
Greensboro, N. C.

HOWARD A. JOHNSON
Supt. of Water Treatment
Danville, Va.



The recent expansion and improvement in Danville's water treating system necessitated extensive changes and additions, all of which were carried to completion without interrupting the service from the existing plant. The new construction project, affecting every phase of the plant from the intake at the Dan River to the Ballou Park Reservoir, brings plant rated capacity up to 9MGD.

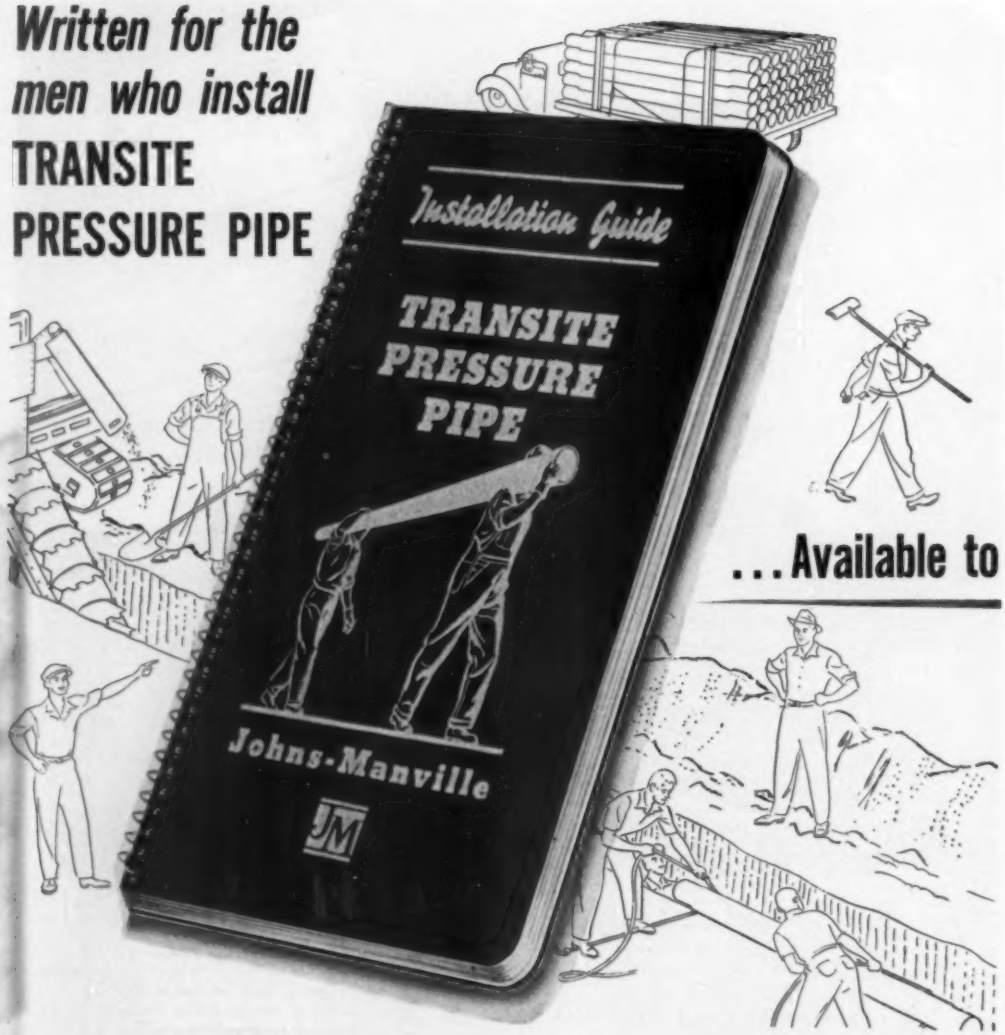
Builders equipment was selected for metering and controlling flow through the plant. This equipment, specified by the engineers, Chas. T. Main, Inc., was installed by V. B. Higgins Co. under the joint direction of Howard A. Johnson, Supt. of Water Treatment; E. M. Hawkins, Jr., Manager of the Water, Gas, and Electric Departments; and L. R. McClung, Supt. of Water Distribution. For Bulletins describing Builders water works equipment, address Builders-Providence, Inc. (Division of Builders Iron Foundry), Providence 1, R. I.

Builders equipment furnished for the Danville Water Filtration Plant:

- Filter Loss of Head and Rate of Flow Indicating and Recording Gauges with Diaphragm Pendulum Actuators.
- 10" Filter Effluent Rate of Flow Controllers.
- 12" Wash Water Rate of Flow Controller.
- 24" Illuminated Wash Water Rate Indicator.
- Filter Operating Tables and Sampler Table.
- Wheeler Filter Bottoms.

BUILDERS PROVIDENCE
Instruments

Written for the men who install TRANSITE PRESSURE PIPE



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AS ITS TITLE IMPLIES, this new Installation Guide was designed especially for those who do the actual work of installing Transite* Pressure Pipe . . . a handy working tool intended to help the man in the field do a good job in an economical way.

But it answers so many questions of general interest about Transite Pipe that it is being offered, without cost, to anyone concerned with the design, construction or operation of a water system.

Send for your copy today. It will give you a new insight into Transite's many practical features that reduce water line installation costs . . . help answer some of the questions you may have about this Johns-Manville asbestos-cement pipe that is contributing to better and more economical water systems for thousands of American cities and towns.

*TRANSITE is a Johns-Manville registered trade mark

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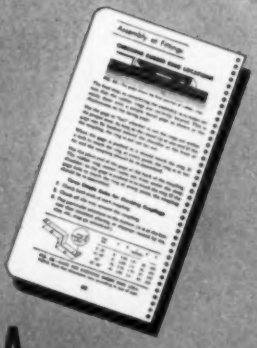
Johns-Manville TRANSITE

FOR BETTER

Q. *How is Transite Pipe assembled in the trench?*

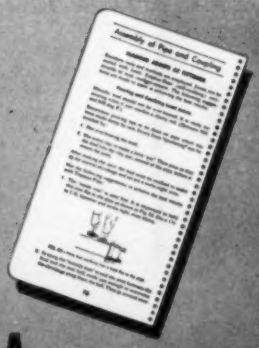
A. By means of the Simplex Coupling, a factory-made joint. See page 38.

Q. *How are joints checked for correct assembly in advance of leakage tests?*



A. By the use of a simple feeler gage as described on page 50.

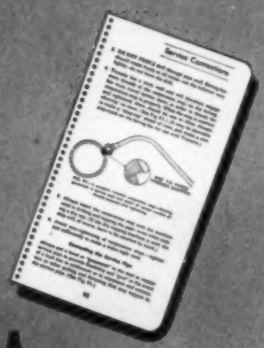
Q. *Are standard practices used for making joints at fittings?*



A. Yes—see "Making Joints at Fittings" page 78.

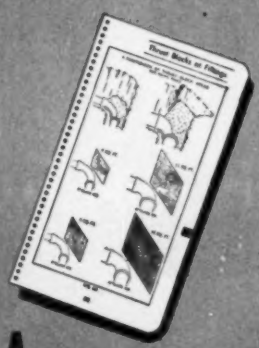
anyone who wants the answers to questions like these

Q. *Can you cut, machine and tap Transite Pipe in the field?*



A. Yes—see "Cutting Transite Pipe" page 72 and "Service Connections" page 91.

Q. *How are size and type of thrust blocks at fittings determined?*



A. The Guide gives helpful data, including tables, construction, and location. See page 82.

Q. *What about trench preparation, supporting the pipe, and tamping?*

A. Standard methods are employed. See pages 16, 23 and 97

Just use the coupon—or write to Johns-Manville, Box 290, New York 16, N. Y. In Canada, address 199 Bay Street, Toronto, Ontario.

ASBESTOS-CEMENT **PRESSURE PIPE**

WATER SERVICE

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Organization_____

Address_____

City_____ State_____

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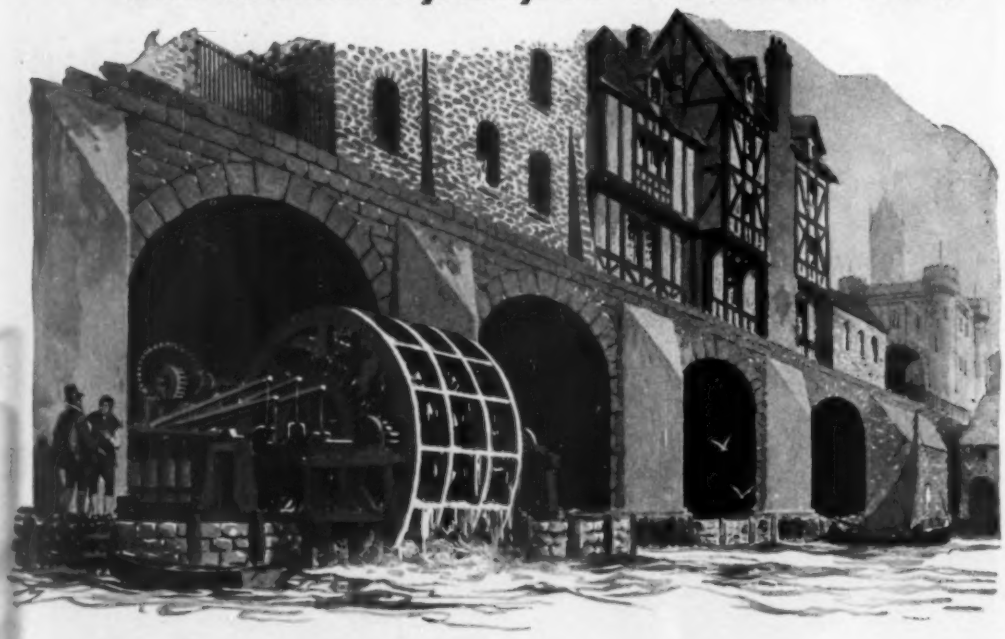
in 1582 *when this machine pumped London's Water*



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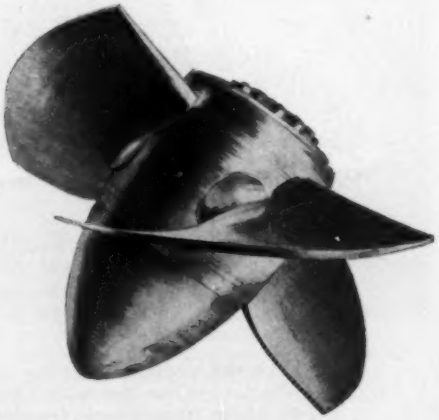

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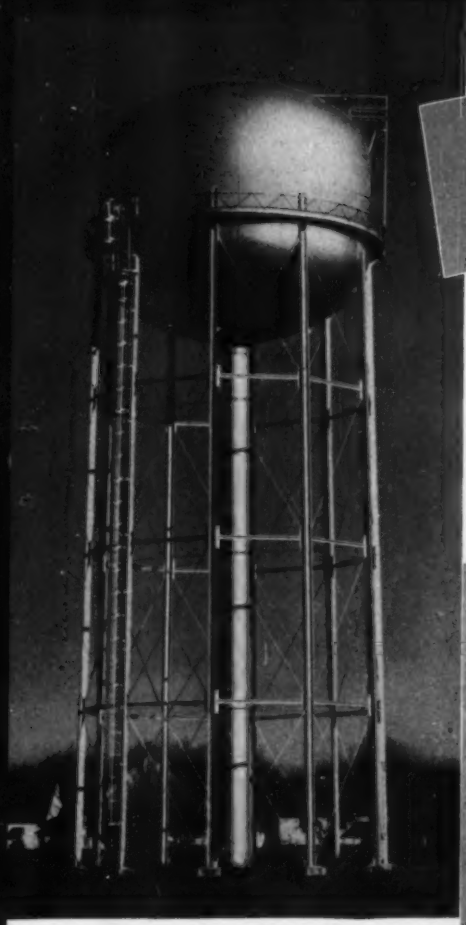

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Elevated Steel Tanks

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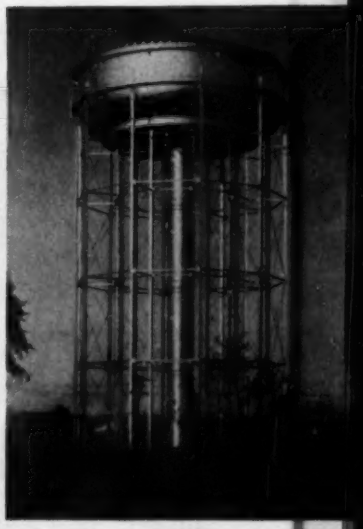

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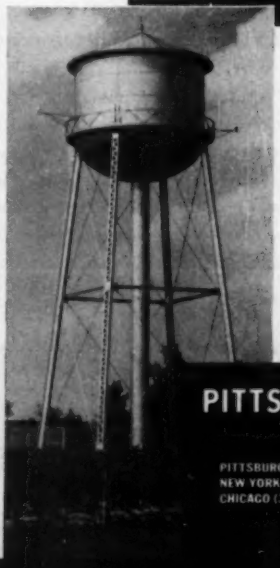

For all municipal water storage requirements, Pittsburgh-Des Moines Elevated Steel Tanks are supplied in a wide range of designs, and in capacities up to 2,500,000 gallons. • Uniform pressures around the clock, supply during interruptions in pumping, lower pumping costs are but a few of the many reasons for this low-cost investment.

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NEW YORK (7)	Room 918, 270 Broadway	DALLAS (1)	1223 Praetorian Bldg.
CHICAGO (3)	1222 First National Bank Bldg.	SEATTLE	926 Lane Street
SANTA CLARA, CAL.	625 Alviso Road		

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SQUARE BOTTOM GATE VALVE

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FREQUENT OPERATION
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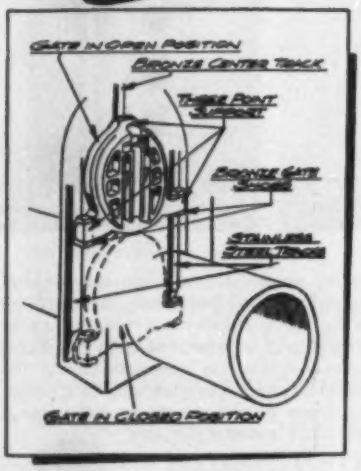

What 3-point Support Means

1—Valve closes easily under high differential head.

2—Valve operates frequently without excessive wear.

3—Valve can be used for throttling without damaging seat rings.

4—The gates are properly supported for operating in vertical lines.

YOU know that throttling service leaves a valve partially open—in which case, an improperly supported downstream gate is under pressure to tilt into the downstream port opening and to score the face of both gate and seat rings.

THIS CAN'T HAPPEN in a Rensselaer Square Bottom Gate Valve—because the gate is properly supported at THREE POINTS during its full length of travel. It can't tilt. The diagram shows why, in detail.

In EVERY respect, this gate valve is designed for long life under severe operating conditions. For instance—during its entire operation, the gate ring is held completely free from contact with the seat ring, by stainless steel tracks, and bronze mounted gate lugs until near the closing point. Then the tracks taper, allowing contact between gate and seat.

Without obligation on your part a Rensselaer representative will be glad to give you the benefit of his experience in Valves, Hydrants and other Rensselaer products. Call our nearest office.

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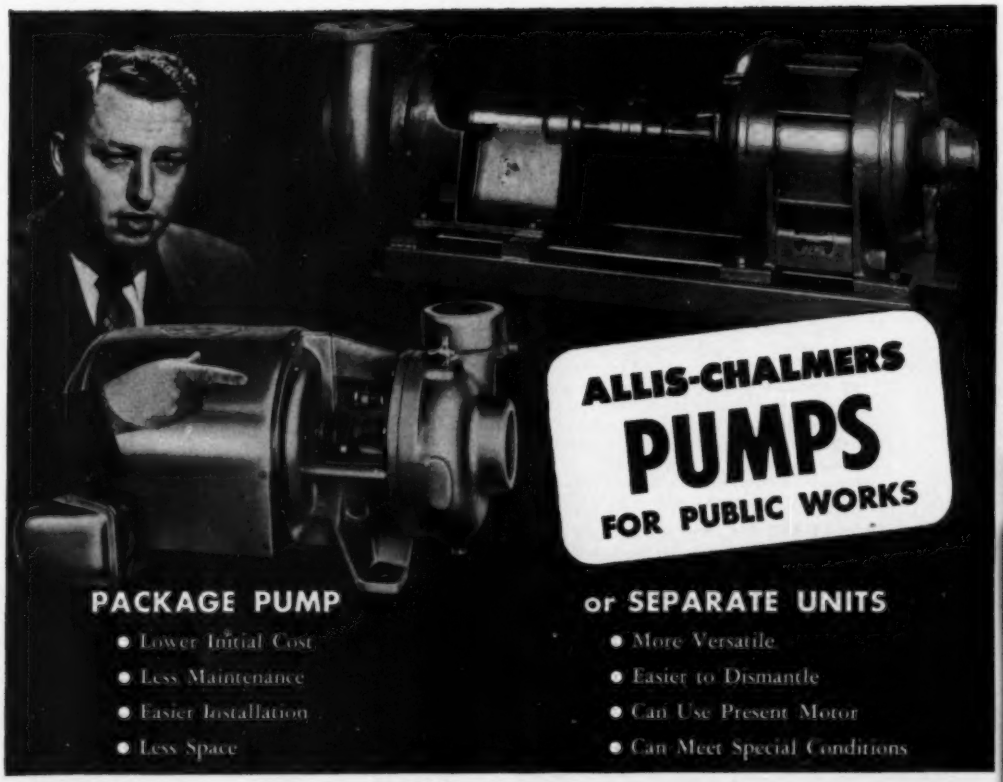
Hydrants • Gate Valves • Square Bottom Valves
Check Valves • Tapping Sleeves and Valves • Air Release Valves

TROY, NEW YORK

Division of Neptune Meter Company

Atlanta, Belo-Cynwyd, Pa., Chicago, Dallas, Denver, Haverhill, Mass., Hornell, N. Y.
Kansas City, Los Angeles, Memphis, Oklahoma City, Pittsburgh, San Francisco, Seattle



Choose THE BEST PUMP FOR YOUR JOB

BROAD PRACTICAL EXPERIENCE in public works plus selection from a complete line of pumps is your guarantee of unbiased recommendation when you call in your nearest A-C pump application engineer.

Whether you require a small pump for booster service, or a larger capacity for a low lift pump station he can help you because he has met and solved similar problems before.

Check On Drives, Too

Allis-Chalmers backs its complete line of pumps with complete drives and control.

A-C is ready to give you service when you need it. Many standard pumps, motors and controls are carried in stock for prompt shipment.

Pumps For Any Size City

Whether your city is large, medium or small, you can depend on Allis-Chalmers public works equipment to provide dependable performance, efficiency and economy-wise

Send For Free Bulletin

Complete details about A-C pumps are in Bulletin 52B6059. Order yours from your nearest A-C Sales Office. A-3068

ALLIS-CHALMERS, 1192A SO. 70 ST.
MILWAUKEE, WIS.

Texrope is an Allis-Chalmers trademark.

ALLIS-CHALMERS

For quality piping... complete selection
Select from the CRANE line

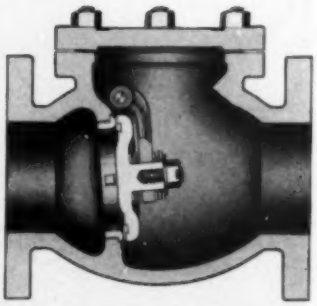
NEW DISC-HINGE CONNECTION GREATLY REDUCES WEAR

Note the improved spring loaded disc-hinge assembly on these Crane Iron Body Swing Check Valves. This patented semi-rigid connection eliminates lost motion, yet has the flexibility needed to assure true seating. Wear at the disc-hinge connection is practically eliminated.

Crane body design assures ample flow area. Disc always swings freely to give unrestricted flow; cannot stick in open position; closes securely when forward flow stops. Bolted cap construction, plus tapped and plugged body openings, provides easy access to all working parts.

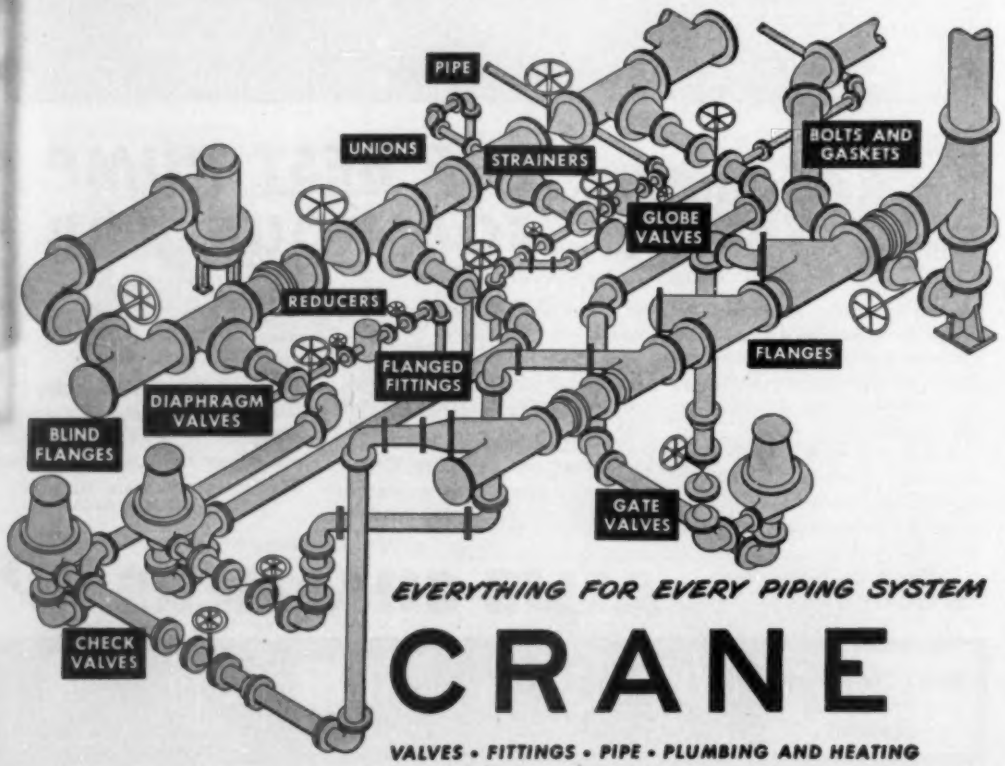
As with all Crane swing checks, these valves can be furnished with outside lever and adjustable weight when extreme sensitivity to flow reversal or to low inlet pressure is desired. Available with flanged, screwed, or hub ends. See your No. 49 Crane Catalog, p. 120-121.

CRANE CO., 836 S. Michigan Ave., Chicago 5, Ill.
Branches and Wholesalers Serving All Industrial Areas



No. 373 brass trimmed check, sizes 2 to 8-in. Also available with leather disc or in all-iron. Sizes 10 to 24-in. have conventional disc-hinge connection. See Crane Catalog for Working Pressures.

THIS SEWAGE STATION PUMP ROOM PIPING, FOR EXAMPLE, CAN BE COMPLETELY EQUIPPED ON ONE ORDER TO CRANE



EVERYTHING FOR EVERY PIPING SYSTEM

CRANE

VALVES • FITTINGS • PIPE • PLUMBING AND HEATING

Chemicals you live by

HOW TO FIGURE OUT THE CHEMICAL BUGS HERE

When the present trend toward stream purification confronts you with a specific problem in the handling and application of chemicals, turn for help to DIAMOND ALKALI.

In this aspect of your job, DIAMOND is capable of rendering expert assistance. DIAMOND has such a broad knowledge of chemicals that it is impossible to detail here *which* application of *what* chemicals might be needed to solve your problem.

DIAMOND *facilities*, however, are dotted across the country at convenient spots, for Technical Service help and for quick delivery of supplies.

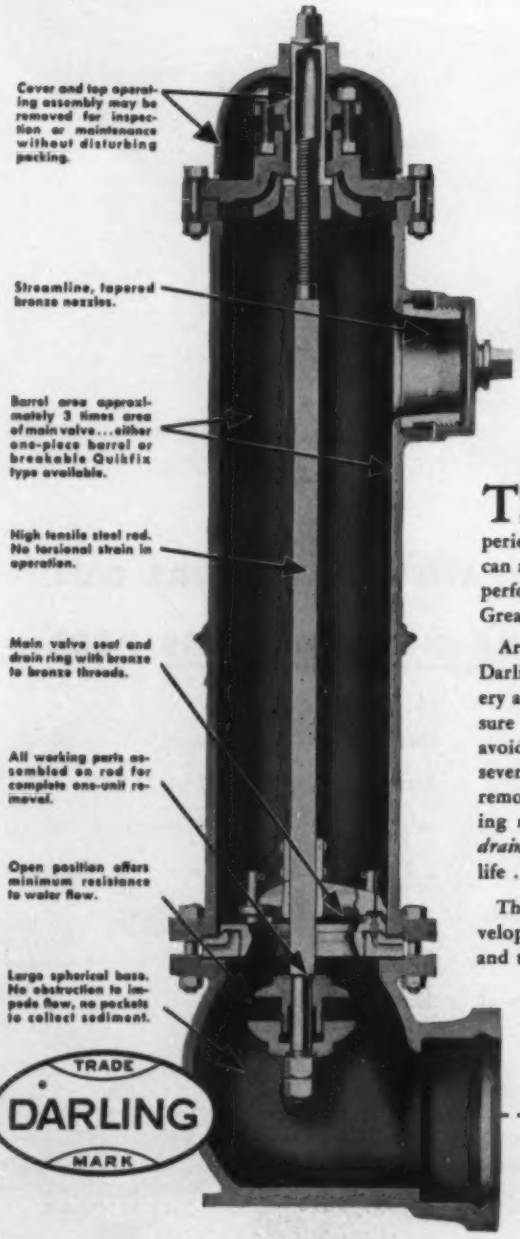
There is a DIAMOND sales office near you: Boston, New York, Philadelphia, Pittsburgh, Cleveland, Cincinnati, Chicago, St. Louis, Memphis and Houston, with representatives in other principal cities.

DIAMOND CHEMICALS FOR WATER TREATMENT

DIAMOND ALKALI COMPANY...CLEVELAND 14, OHIO

DIAMOND ALKALI CHEMICALS

Peace of mind sums it up!


Cover and top operating assembly may be removed for inspection or maintenance without disturbing packing.
Streamline, tapered bronze nozzles.
Barrel area approximately 3 times area of main valve... either one-piece barrel or breakable Quikfix type available.
High tensile steel rod. No torsional strain in operation.
Main valve seat and drain ring with bronze to bronze threads.
All working parts assembled on rod for complete one-unit removal.
Open position offers minimum resistance to water flow.
Large spherical base. No obstruction to impede flow, no pockets to collect sediment.
TRADE
DARLING
MARK

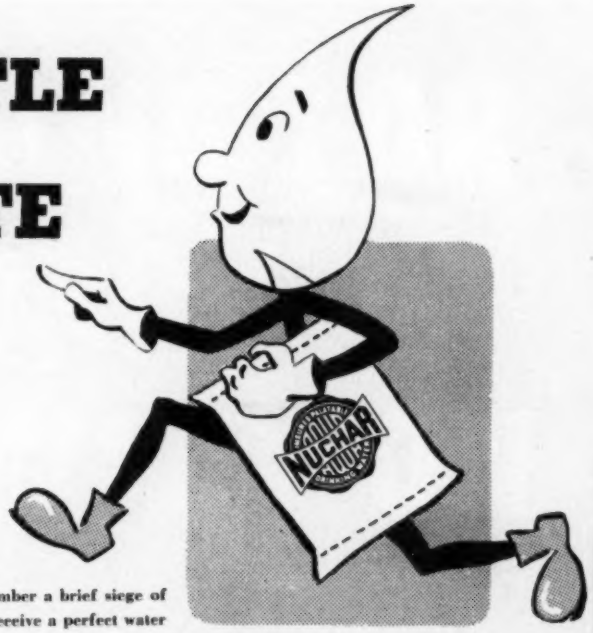
THIS man shares responsibility in his town for fire-fighting efficiency and operating cost. Experience has shown him that on both counts he can rely on Darling hydrants for the finest kind of performance . . . year around, year in, year out! Greater peace of mind is another way of putting it.

Are you familiar with all the *advanced* features of Darling hydrants? These include peak water delivery at the nozzles with no perceptible loss of pressure . . . positive, automatic flushing of drains to avoid freeze-ups . . . prevention of flooding despite severe traffic damage . . . fast, simplified, *one-man* removal and inspection of *all* working parts including main valve, *main valve seat,* drain valve and *drain valve seats* . . . unsurpassed ruggedness and life . . . modern, good-looking exterior.

These are only a few of the Darling features developed to ease your mind on hydrant performance, and to ease your budget on over-all cost! Catalog 17M describes *all* the features in detail, tells all about Darling hydrants for every known service both normal and unusual. We'll be happy to send you a copy.

DARLING
VALVE & MANUFACTURING CO.
Williamsport 11, Pa.

TOO LITTLE and TOO LATE



THE consuming public will long remember a brief siege of unpalatable water even though they receive a perfect water supply for the remainder of the year.

Your best insurance against these consumer complaints is to keep an adequate supply of Aqua Nuchar Activated Carbon on hand. Then, when a sudden taste or odor appears, it can be quickly controlled by large dosages of carbon. But remember, there seems to be a common inclination not to use the required high doses during short periods of intense tastes and odors. This is definitely a false economy when measured in terms of long range consumer relations.

Many water plant operators control tastes and odors *and* their customers tempers by constant small dosages of Aqua Nuchar Activated Carbon. This prevents a sudden taste or odor condition from getting out of control, since a relatively small increase in the amount of Aqua Nuchar will quickly restore the palatability of the water.

OTHER PRODUCTS: *Snow Top Precipitated Calcium Carbonate* • *Nuchar Activated Carbons* • *Liqro Crude Tall Oil* • *Indusoil Distilled Tall Oil* • *Tallene Tall Oil Pitch* *Tallex Abietic Acid* • *Sulfate Wood Turpentine* • *Alpha Pinene* • *Beta Pinene* *Polycel Cellulose Fibers* • *Indulin (lignin)*

Plan to attend the A.W.W.A. Annual Convention at Philadelphia, May 21-26

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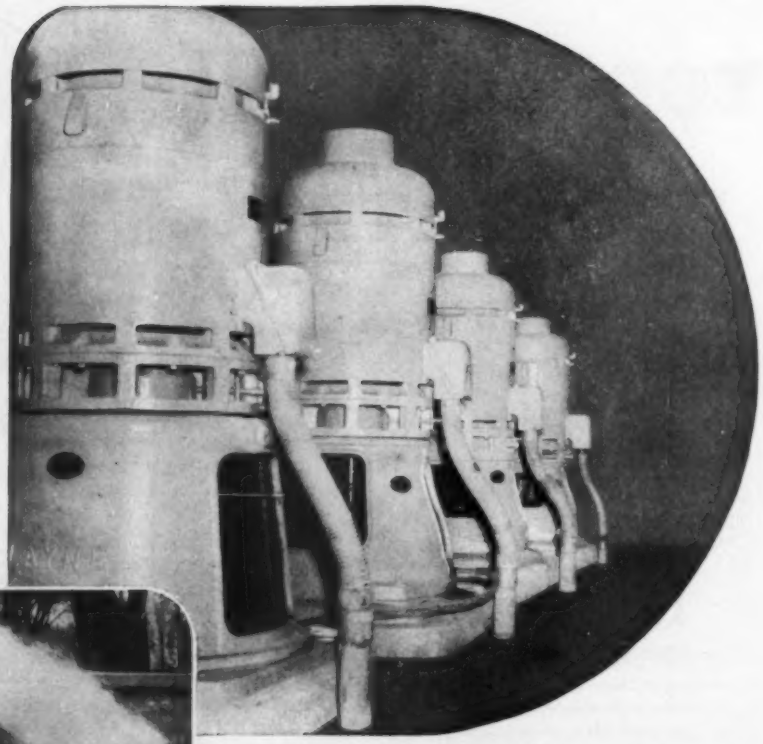


Just Ask Most Anybody

While there is some chance that we might be prejudiced, our people believe that Layne well water systems are the very finest now being built. However, you can get your facts first hand by doing a little investigating of your own. Just ask most anybody who owns a Layne well water system if he considers them to be okay?—Are they low in upkeep cost—big in volume production—designed right—built of good stuff and then installed and serviced by people who seem to know their business?

We don't know exactly what kind of answers you will get, but according to past records, the "know how" boys,—operating engineers, plant managers, water works superintendents and cost accountants will be mighty, mighty complimentary. They are the first to recognize and show genuine appreciation of good equipment. A list of your nearby Layne well water system owners will be sent on request. For other helpful material —illustrated catalogs and folders, address

LAYNE & BOWLER, INC.
GENERAL OFFICES, MEMPHIS 8, TENN.

LAYNE ASSOCIATED COMPANIES

ASSOCIATED COMPANIES—Layne-Arkansas Co., Stuttgart, Ark. ★ Layne-Atlantic Co., Norfolk, Va. ★ Layne-Central Co., Memphis, Tenn. ★ Layne-Northern Co., Mishawaka, Ind. ★ Layne-Louisiana Co., Lake Charles, La. ★ Louisiana Well Co., Monroe, La. ★ Layne-New York Co., New York City ★ Layne-Northwest Co., Milwaukee, Wis. ★ Layne-Ohio Co., Columbus, Ohio ★ Layne-Pacific, Inc., Seattle, Wash. ★ The Layne-Texas Co., Ltd., Houston, Tex. ★ Layne-Western Co., Kansas City, Mo. ★ Layne-Minnesota Co., Minneapolis, Minn. ★ International Water Corp., Pittsburgh, Pa. ★ International Water Supply, Ltd., London, Ont. ★ Layne-Hispano Americana, S.A., Mexico, D. F. ★ General Filter Company, Ames, Iowa.

LAYNE

WELL WATER SYSTEMS

VERTICAL TURBINE PUMPS

LOOKING FOR IMPROVED COAGULATION ?

FREE INFORMATION ON REQUEST

FROM THE

TENNESSEE CORPORATION
Atlanta, Georgia — Lockland, Ohio

ON FERRI-FLOC, THE NEW FERRIC IRON COAGULANT. FREE 35 PAGE BOOK ON WATER AND SEWAGE TREATMENT WITH...

FERRI-FLOC

STAYS PUT

...because

Aluminum Lasts!

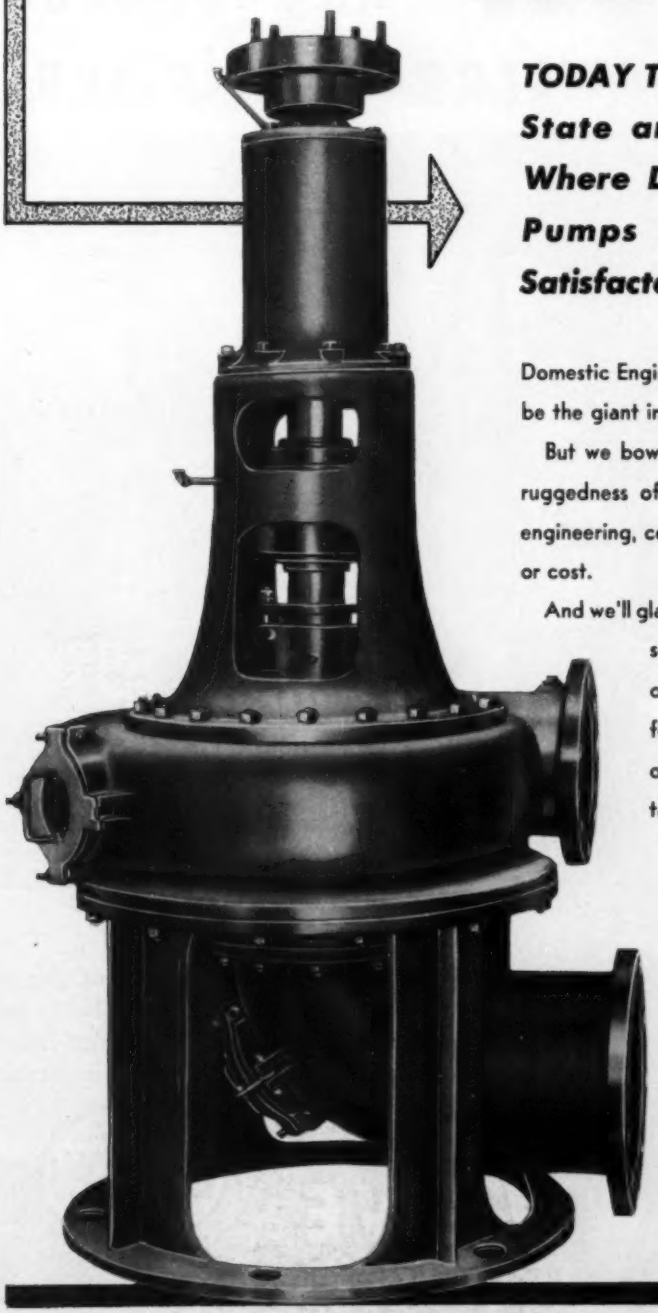
ALCOA FORGED ALUMINUM MANHOLE STEPS AND LADDER RUNGS

Here's a new kind of metal step that's strong, safe, durable. Because it is made of highly corrosion-resistant Alcoa Aluminum Alloy, this forged step requires virtually no maintenance, lasts years longer. It is safe—non-sparking, and grooved for a firm foothold. Easily installed in any type of masonry, this sturdy aluminum step will take a 1,000-pound load without permanent deformation.

Available in three sizes for easy installation in any type of masonry, outside or inside. Call your nearby Alcoa Sales Office for information and prices. Or write for free folder. ALUMINUM COMPANY OF AMERICA, 1809E Gulf Bldg., Pittsburgh 19, Pa.

SAFE • NON-SPARKING • STRONG • DURABLE • ECONOMICAL

WANT PROOF?



TODAY There Are 192 City, State and Federal Units Where Domestic Sewage Pumps are Performing Satisfactorily.

Domestic Engine & Pump Company may not be the giant in this field.

But we bow to no one when it comes to ruggedness of our sewage pumps, design, engineering, construction, ease of operation or cost.

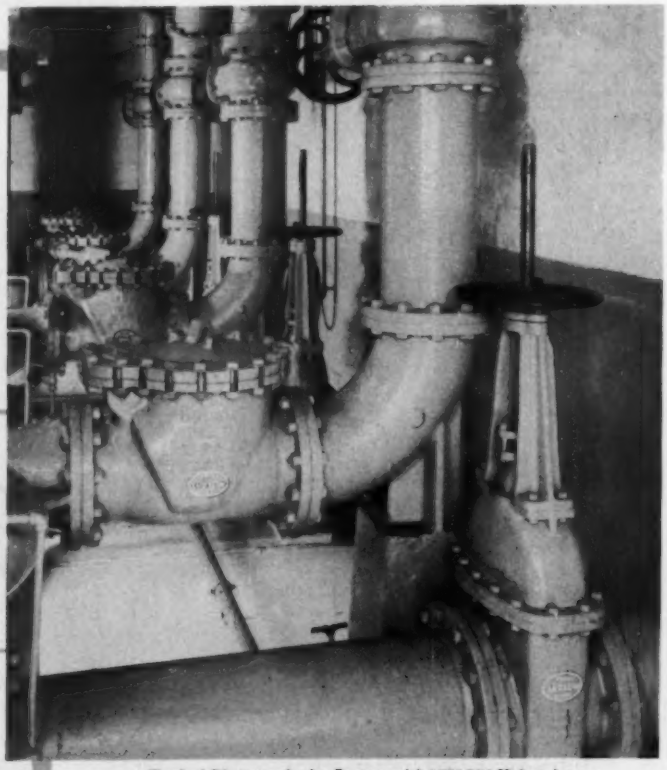
And we'll gladly supply any interested person with names, places, dates of installation or any other information desired. The history of Domestic Sewage Pumps talks for itself.

Domestic Manufactures Sump Pumps—Sludge Pumps—Vertical Flexible—Vertical Open Shaft and Horizontal Sewage Pumps for normal or heavy duty.

"DOMESTIC"
ENGINE & PUMP CO.
SHIPPENSBURG, PA.

LUDLOW = QUALITY + RUGGEDNESS

for your Sewerage Equipment



Typical Photograph of a System with **LUDLOW** *Valves in a Sewerage Pumping Station*

LUDLOW operates a completely integrated plant with its own Iron, Bronze and Steel Foundries — Machine Shops, Pattern Shops — Completely Modern Metallurgical Laboratory and Engineering Department — plus rigid inspection and testing operation control.

The LUDLOW VALVE MFG·CO·INC·TROY·N·Y·

SINCE 1866

TRADE LUDLOW MARK

a "Boost" for any water system!

The dependability that features the performance of any Fairbanks-Morse Centrifugal Pump provides a "boost" for municipal water systems. In this booster installation, for example, three Fairbanks-Morse 12-inch Figure 5814 Split Case pumps each deliver 5600 G.P.M. against a maximum head of 100 feet . . . and will continue to deliver *dependably* for years.

In any application, you'll find the biggest "boosters" for Fairbanks-Morse Pumps are the men who use them. Why not profit by their experience and check your pump requirements with your Fairbanks-Morse Pump Dealer or branch pump engineer. Fairbanks, Morse & Co., Chicago 5, Ill.

FAIRBANKS-MORSE.

a name worth remembering

DIESEL LOCOMOTIVES AND ENGINES • ELECTRICAL MACHINERY • PUMPS • SCALES
HOME WATER SERVICE AND HEATING EQUIPMENT • RAIL CARS • FARM MACHINERY

A Dresser-coupled steel line delivers water cheaper...

The cheapest way to deliver water to the place where it turns into revenue is with a Dresser-Coupled steel line—the line that

- **Cuts Installation Costs**
- **Cuts Leakage Losses**
- **Cuts Maintenance Costs**

New water lines rarely follow the line of least resistance. In city streets, numerous other utility lines, often uncharted, must be circumvented with a minimum of interference. Ditches must be kept narrow and be closed up rapidly. Pipe and joints must be vibration-proof.

The longer lengths of lightweight steel pipe and easy-to-install, flexible Dresser Couplings pay off in faster job completion, elimination of many costly specials and a generally more satisfactory job. Joining crews are small, need have no special skills. Construction can proceed in any weather. Joints are 100% tight—made to last. Glass-smooth linings assure high sustained carrying capacity.

See your Dresser Engineer or write today for literature.

In Somerville, Mass., this 36" steel line circumvented many electric conduits, water, sewer and gas pipes. Dresser Couplings made it possible to do this with little disturbance to existing structures.

BE SURE **you get the best line at the best price. Put steel pipe and Dresser Couplings in your specifications.**

DRESSER "FLEXIBLE-TIGHT" COUPLINGS

Dresser Manufacturing Division, 59 Fisher Avenue, Bradford, Pa. (One of the Dresser Industries). In Texas: 1121 Rothwell Street, Houston. In Canada: 629 Adelaide St., West, Toronto, Ontario. Sales Offices: New York, Chicago, Houston, Philadelphia, San Francisco.

Worthington-Gamon

WATCH DOG WATER METERS

The meter used by thousands of municipalities in the U. S. and abroad.

SURE TO MEET YOUR SPECIFICATIONS FOR ACCURACY, LOW MAINTENANCE, LONG LIFE

Before you invest in water meters, get acquainted with the design and performance advantages which make Worthington-Gamon Watch Dog Water Meters first choice of so many municipalities and private water companies in the United States.

WATCH DOG WATER METERS

"Watch Dog" models . . . made in standard capacities from 20 gpm up; frost-proof and split case in household sizes. Disc type, Turbine type or Compound type. Write for Bulletin.

WORTHINGTON-GAMON METER COMPANY

296 South Street, Newark 5, New Jersey

Subsidiary of

WORTHINGTON

PUMP AND MACHINERY CORPORATION

FILER & STOWELL SLUICE GATES

MANUAL
ELECTRIC
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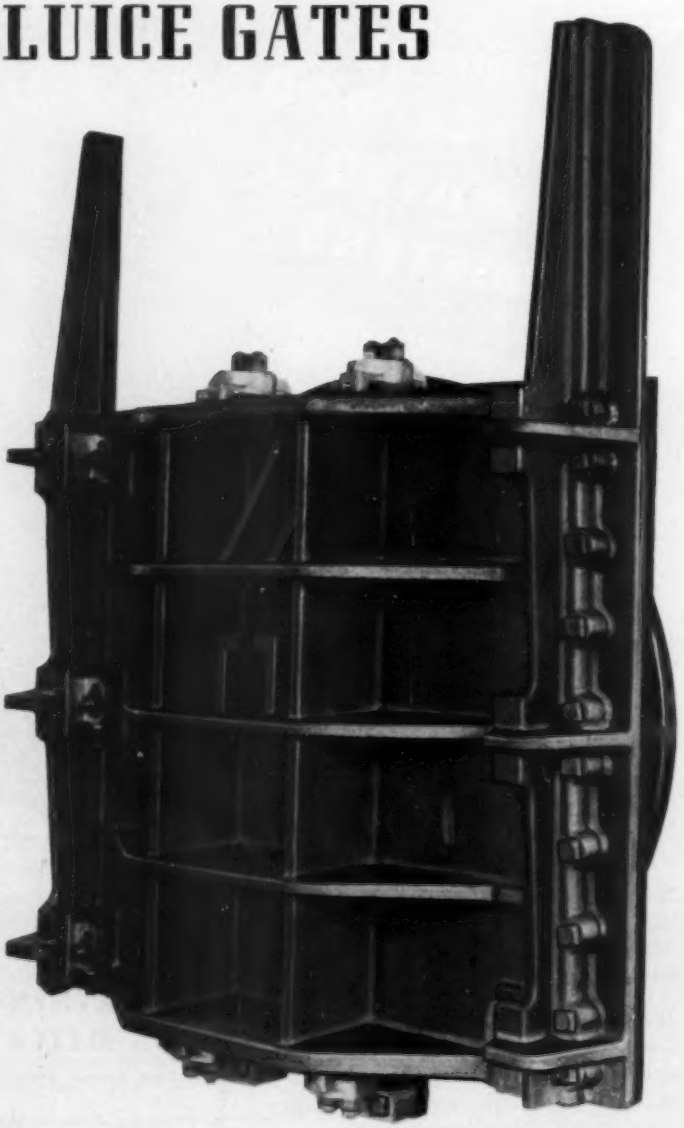


The sturdy design of Filer & Stowell Sluice Gates furnish long trouble free service. They have been standardized throughout for ease of installation and operation. Available in all standard sizes to meet all usual conditions and special designs to meet your unusual conditions.

THE FILER & STOWELL COMPANY

147 E. BECHER STREET, MILWAUKEE 7, WISCONSIN

"What d'ya mean, using all Everdur might cost less?"

JOE: *"I suppose you think you're saving money by using Everdur for only part of this job."*

JIM: *"Of course. These other materials are cheaper."*

JOE: *"But you know they won't resist corrosion as long as Everdur—you're going to have to replace them eventually."*

JIM: *"We-e-ell . . ."*

JOE: *"Then there's the fact that Everdur costs less to fabricate. It's easy to work and machine."*

JIM: *"Yeah?"*

JOE: *"Sure. And don't forget, built-up assemblies are lighter . . . easier to operate. That cuts costs."*

JIM: *"Okay, okay. You win. I guess we will be money ahead to use Everdur all around."*

Dozens of sewage plant and waterworks case histories testify to the efficiency and long-range economy of using Everdur* to resist corrosion in such installations. These ANACONDA Copper-Silicon Alloys combine the corrosion resistance of copper with high tensile strength.

Everdur is available in practically all wrought forms such as sheets, plates, rods, bars, and in structural shapes such as angles, channels, tee shapes and "I" beam sections; also in casting ingots. If you would like to know more, just write to The American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

*Reg. U. S. Pat. Off.

Where corrosion resistance counts—use Everdur

ANACONDA

COPPER-SILICON ALLOYS

Save dollars by the mile

with K&M "Century"® Asbestos-Cement Pipe

Miles of dollar savings and miles of highly improved water main service are being laid today, in numerous localities, as more and more use is made of K&M "Century" Asbestos-Cement Pipe. The alert officials, engineers, planners and other authorities who adopt this advanced K&M Pipe provide mains which are inherently resistant to threats of soil corrosion, electrolysis, tuberculation and flow reduction.

The same proved K&M Asbestos-Cement combination that makes all this possible, likewise assures strong pipe of remarkable lightness. New economies are effected in shipping, haulage and handling. Costs are cut still more by the use of K&M "Century" Simplex Couplings which permit deflection with standard pipe lengths, and also simplify any needed alignment before backfilling. High resistance too, is provided against traffic stresses and earth settlement.

Years of service do not weaken K&M "Century" Pipe. It can be recovered and relaid in its original pressure class. Add the long-term maintenance savings to the installation economies and you can plainly figure why the strong trend today is to K&M "Century" Asbestos-Cement Pipe.

KEASBEY & MATTISON
COMPANY • AMBLER • PENNSYLVANIA

Nature made Asbestos... Keasbey & Mattison has made it serve mankind since 1873

See us at...

BOOTHS 341 and 343 pictured above,
MAY 21-26, 1950
Convention Hall, Philadelphia

American Water Works Association Annual Convention

THE SPIRAL CONVEYOR

Jeffrey Spiral Conveyor handling alum and lime in a large Water Works Plant. A section of Spiral flight is also shown.

A COMPACT INSTALLATION

Used extensively in Water Works Plants for handling lime, alum or other chemicals—saving time and cost. Jeffrey Spirals make compact installations—can be made dust-tight. No return strand. Capacities vary with size of unit.

Photo above shows a Jeffrey Spiral installation in a large Ohio Water Works Plant. Note the clamped cover used when handling dusty material—also the various rack and pinion valves in the trough bottom for delivery of material when and where needed.

Catalog No. 803-A fully describes and pictures Jeffrey Spirals. Catalog No. 775-A covers our complete line of Sewage, Water and Industrial Waste Treatment equipment.

Sludge Collectors
Sludge Elevators
Grit Washers & Collectors
Flocculation Equipment
Bar Screens
Spiral Conveyors
Chains—Bearings
Grinders

THE JEFFREY MANUFACTURING COMPANY

Established 1877

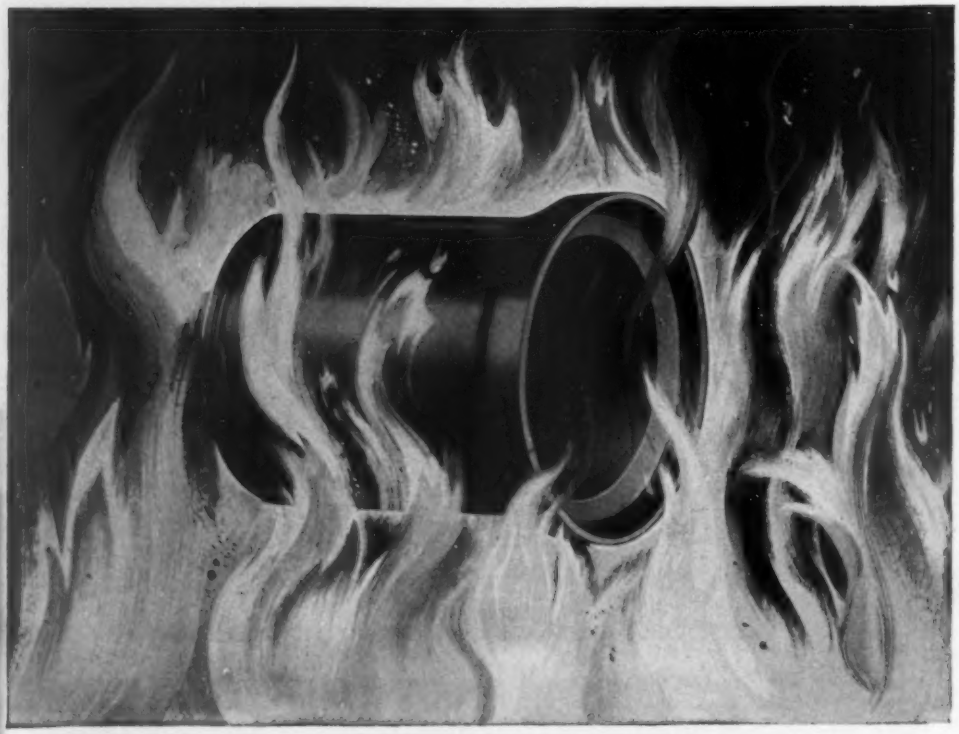
996 North Fourth St., Columbus 16, Ohio

Complete Line of Material Handling, Processing and Mining Equipment

JM

Baltimore 2	Chicago 1	Detroit 13	Jacksonville 2	Pittsburgh 22
Birmingham 3	Cincinnati 2	Harlan	Milwaukee 2	St. Louis 1
Boston 16	Cleveland 13	Houston 2	New York 7	Salt Lake City 1
Buffalo 2	Denver 2	Huntington 19	Philadelphia 3	Scranton 3

Jeffrey Mfg. Co., Ltd., Head Office & Works: Montreal



CLAY PIPE...fused by fire for EVERLASTING service

VITRIFICATION — the heat-bonding process that makes Clay Pipe tough, corrosion-proof, and everlasting — takes place at temperatures exceeding 2000° F. Under carefully controlled firing, the minute particles of rock that have been formed into Clay through centuries of nature's purification are fused *permanently* together. Vitrified Clay Pipe needs no coating to protect it from the corrosive action of sewage, ground waters, soils, or industrial waste. It's chemically inert, completely safe from the acid attack that destroys so many materials. No other pipe offers all the *necessary* advantages of Vitrified Clay Pipe. That's why it's universally preferred for sewerage and drainage installations.

NATIONAL CLAY PIPE MANUFACTURERS, INC.

1105 Huntington Bank Bldg., Columbus 15, Ohio
703 Ninth and Hill Bldg., Los Angeles 15, Calif.
100 N. LaSalle St., Rm. 2100, Chicago 2, Ill.
206 Connally Bldg., Atlanta 3, Ga.

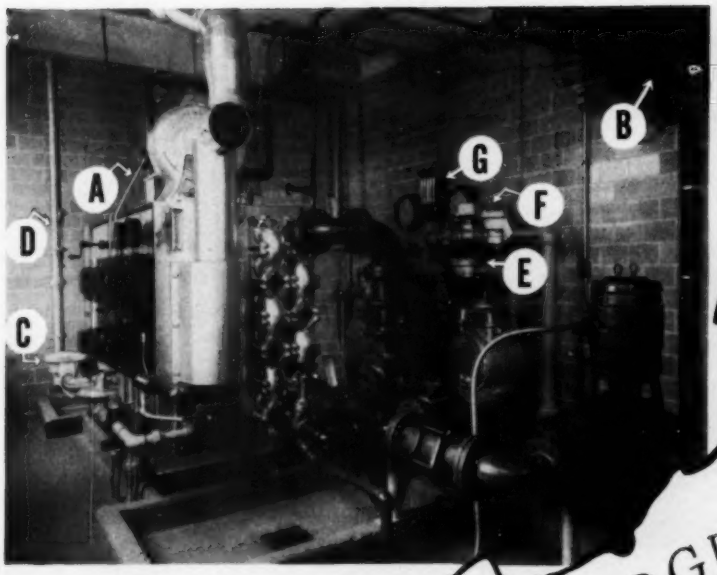
SPECIFY *Vitrified* **CLAY PIPE**

STANDARD-STRENGTH CLAY PIPE

CHANNEL CLAY PIPE

CLAY PIPE FITTINGS

C-350-E



SEWAGE TREATMENT PLANT

Designed By
Alexander Potter Assoc's
NEW YORK, N. Y.

AT

Winchester

The well designed digester control room includes the following items of P. F. T. Equipments . . .

(A) P. F. T. Model 370 Digester Heater & Heat Exchanger, with output of 370,000 B. t. u. per hour for digester heating, plus 185,000 B. t. u. per hour for building heating controlled through "DM" controls.

(B) Space heater with hot water supplied by circulating pump located on Heater & Heat Exchanger Units taking hot water from bath of unit.

(C) P. F. T. 2" Flame Trap on gas supply line to Heater & Heat Exchanger. (a second unit not shown)

(D) P. F. T. Pressure gauge on gas supply line.

(E) P. F. T. 2" Low Pressure Check Valve on digester gas supply line. (a second unit not shown)

(F) P. F. T. 2" Pressure relief and Waste Gas Flame Trap on line to P. F. T. 3" Waste Gas Burner (not shown).

(G) P. F. T. Five Scale Pressure Gauge.

THIS MODERN SEWAGE TREATMENT PLANT ALSO INCLUDES:

2 — P. F. T. Floating Covers to fit 43'0" diameter digester.
2 — P. F. T. Supernatant Selectors.
2 — P. F. T. Supernatant Gauge, Sight Glass & Sampler Units.
4 — P. F. T. Manually operated drip traps.

P.F.T.

PACIFIC FLUSH TANK CO.

SEWAGE TREATMENT EQUIPMENT EXCLUSIVELY SINCE 1893

4241 RAVENSWOOD AVENUE CHICAGO 13, ILLINOIS

NEW YORK • LOS ANGELES • SAN FRANCISCO • CHARLOTTE, N. C. • DENVER • TORONTO

New 200 mgd. Water Line in Denver Uses 10 Miles of *CONCRETE PIPE*

DENVER'S new water line, "Conduit No. 20," extending from its filter plant at Kassler to the city's reservoir at Marston Lake, is supplying the city with 200 mgd. This giant water line consists of 25,252 ft. of 90-in. concrete pipe in 16-ft. sections with 8-in. walls. Each section weighs about 21 tons.

Conduit No. 20, a 3¾ million dollar project, replaces old wood stave lines laid many years ago over a more indirect route.

This giant new water line is the latest in a series of water line installations in the Denver area. During 1948 and 1949 earlier installations in this project used 30,003 ft. of concrete water pipe in sizes ranging from 24-in. to 42-in.

Denver's extensive use of concrete pipe is typical of the preference for concrete pipe water lines throughout the nation. That's because concrete pipe has the strength to resist severe impact and to sustain heavy overburdens, because it has the durability to render ***low-annual-cost*** service. Concrete pipe, moreover, has no tuberculation to impair its hydraulic efficiency. Its dense structure and joints, which can be made watertight, prevent leakage and infiltration.

Taste, odor and dirty water difficulties are minimized in concrete pipe water lines. That's because concrete pipe meets every operating requirement and in addition provides ***low-annual-cost*** service that pleases engineers and taxpayers alike.

●

Photos show two construction views of Denver's Conduit No. 20. Pipe made by Lock Joint Pipe Company, prime contractor. Laying operation by Gordon-Bressi-Bevanda.

PORTLAND CEMENT ASSOCIATION

33 WEST GRAND AVENUE, CHICAGO 10, ILLINOIS

A national organization to improve and extend the uses of portland cement and concrete through scientific research and engineering field work

No water treating plant is completely modern without

BECKMAN pH CONTROL

Beckman pH Control is the tool with which modern water treating engineers are reducing purification costs, increasing operating efficiencies and insuring a better, more uniform water supply in municipalities large and small from coast to coast.

Because Beckman Glass Electrode pH Equipment has pioneered one important pH advancement after another, it is widely recognized as the most advanced pH equipment available for all types of water and sewerage treating plants. It is installed in plants—both large and small—throughout the country.

No matter whether you are building a new plant or modernizing an older one—and regardless of its size—it will pay you to get the complete story on how Beckman pH equipment will step up efficiencies and cut costs on *your* operations.

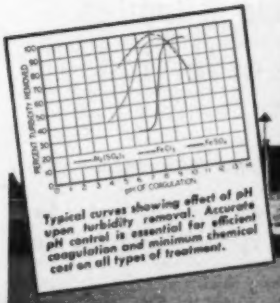
Our trained engineers have had wide experience in this type of application and will gladly consult with you and make recommendations on the most efficient methods of solving *your particular* pH control problems. This service incurs no obligation. Write us outlining your pH problems.

This Beckman Automatic pH Indicator is the most advanced pH instrument available. Fully automatic, it gives continuous indication of pH and also operates standard types of potentiometric recording and controlling equipment.

FREE! Send for this special booklet "pH in Water Treatment and Sewage Disposal." Full of helpful technical information and application data. Please ask for Bulletin 180A!

BECKMAN INSTRUMENTS
NATIONAL TECHNICAL LABORATORIES
South Pasadena 20, California

ONE OF THE LARGEST water treating operations in the country—the Los Angeles Metropolitan Water District—uses Beckman pH Equipment throughout to insure maximum efficiency of its treating operations. This is but one of many similar Beckman pH installations in treating plants, large and small.



Typical curves showing effect of pH upon turbidity removal. Accurate pH control is essential for efficient coagulation and minimum chemical cost on all types of treatment.

BECKMAN INSTRUMENTS CONTROL MODERN INDUSTRIES

"Every individual connected with water purification or sewage works should subscribe to this publication. I have introduced it to a host of friends in this field"

Testimonials such as this from subscribers to WATER & SEWAGE WORKS really tell the story. The man who reads and uses the magazine as an aid in his work knows how much it will benefit other workers in the field.

The great REFERENCE & DATA issue alone is worth more than the yearly subscription rate. In it you will find formulae, charts and illustrations covering information not obtainable in any other one source.

Supply of 1950 REFERENCE & DATA number is limited. If you are not a subscriber send your order today!

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- *If you are interested in the water field only you get all the authoritative data on this subject.*
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- *If you are interested in both subjects you get all the information in this one monthly magazine.*

pH CONTROL

COAGULATION CONTROL

FILTRATION CONTROL

CORROSION CONTROL

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TASTE AND ODOR CONTROL

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SEWAGE TREATMENT

DECHLORINATION CONTROL

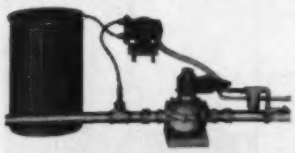
Control Starts Here

WITH

% PROPORTIONEERS %

PROPORTIONING PUMPS • DIATOMACEOUS EARTH FILTERS

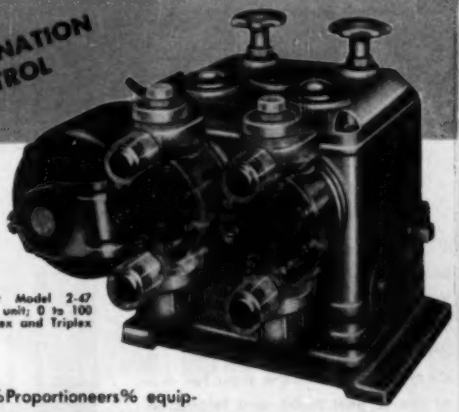
FOR PUMPED WATER SYSTEMS Constant Rate Feeder — Heavy Duty Midget Chem-O-Feeder. Feeds 0-7½ GPH at 0 to 85 p.s.i.



FOR VARIABLE FLOW SYSTEMS Flow Proportional Feeder — Automatic and Proportional Chem-O-Feeder Feeds 0-5 GPH at 4-100 p.s.i.

FOR YOUR CAMP Du-Self — a complete Package Unit — for water treating. For flows up to 25 GPM and 75 p.s.i.

FOR YOUR SWIM POOL For crystal clear swim pool water — Pur-O-Cel Diatomaceous Earth Filter, Triplex Model.



New Duplex Chem-O-Feeder Model 2-47 capacity 8 GPH each feeding unit; 0 to 100 p.s.i. Available Simplex, Duplex and Triplex models.

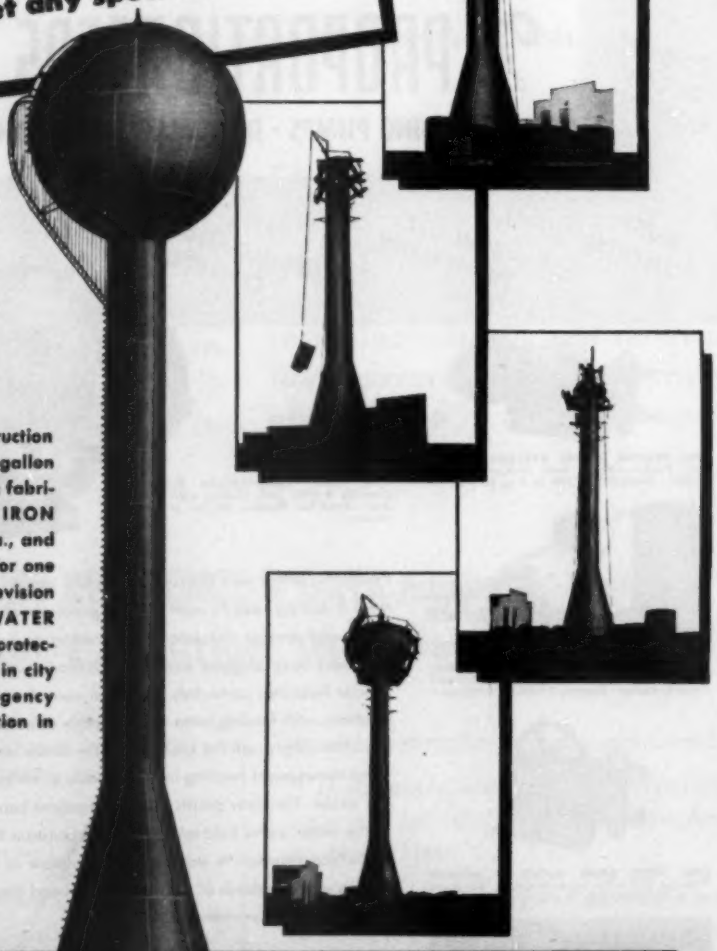
Precision control with %Proportioneers% equipment is solving today's most difficult problems of water and sewage treatment — eliminating inaccurate, hit-or-miss methods that for years have plagued engineers. %Proportioneers% new Duplex Chem-O-Feeder illustrates up-to-date, precision control at its best. It feeds two different solutions, with feeding rates each instantly adjustable while the pump is operating. You simply turn the knobs to set the stroke lengths — a magnifying register glass shows exact reading in thousandths of an inch over a range of 2 to 13 cc per stroke. The clear plastic See-Thru reagent heads handle any chemical used in the water works field and reveal the constant flow of solution feed. The line of %Proportioneers% equipment is complete — over 30,000 installations are setting new standards of precision control and dependable operation. Write for bulletins and recommendations.

% PROPORTIONEERS, INC. %

350 Harris Avenue, Providence 1, R. I.

HAMMOND

WATER SPHERES
ELEVATED TOWERS
STANDPIPES AND RESERVOIRS
to meet any specification



Illustrating 4 stages of construction and the completed 140,000 gallon Water Sphere, 130 feet high; fabricated in the HAMMOND IRON WORKS shops at Warren, Pa., and erected in the middle west for one of the largest radio and television firms. This HAMMOND WATER SPHERE was erected for fire protection in the event of a break in city water mains or any emergency which would cause a reduction in water pressure of city mains.

1900-GOLDEN ANNIVERSARY-1950
HAMMOND, INC.
A HALF CENTURY OF EXPERIENCE

HAMMOND IRON WORKS
WARREN, PA.
BRISTOL, PA.

DANVILLE, VA.

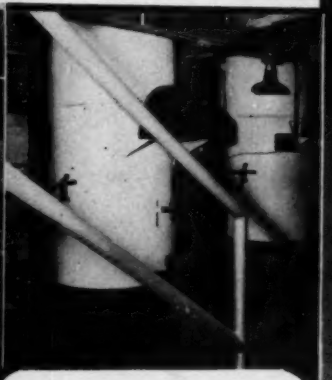
Water Filtration Plant

(COMPLETED IN 1949)

CHAS. T. MAIN, INC.
Engineers
Boston, Mass.

V. B. HIGGINS CO.
Contractors
Greensboro, N. C.

HOWARD A. JOHNSON
Supt. of Water Treatment
Danville, Va.



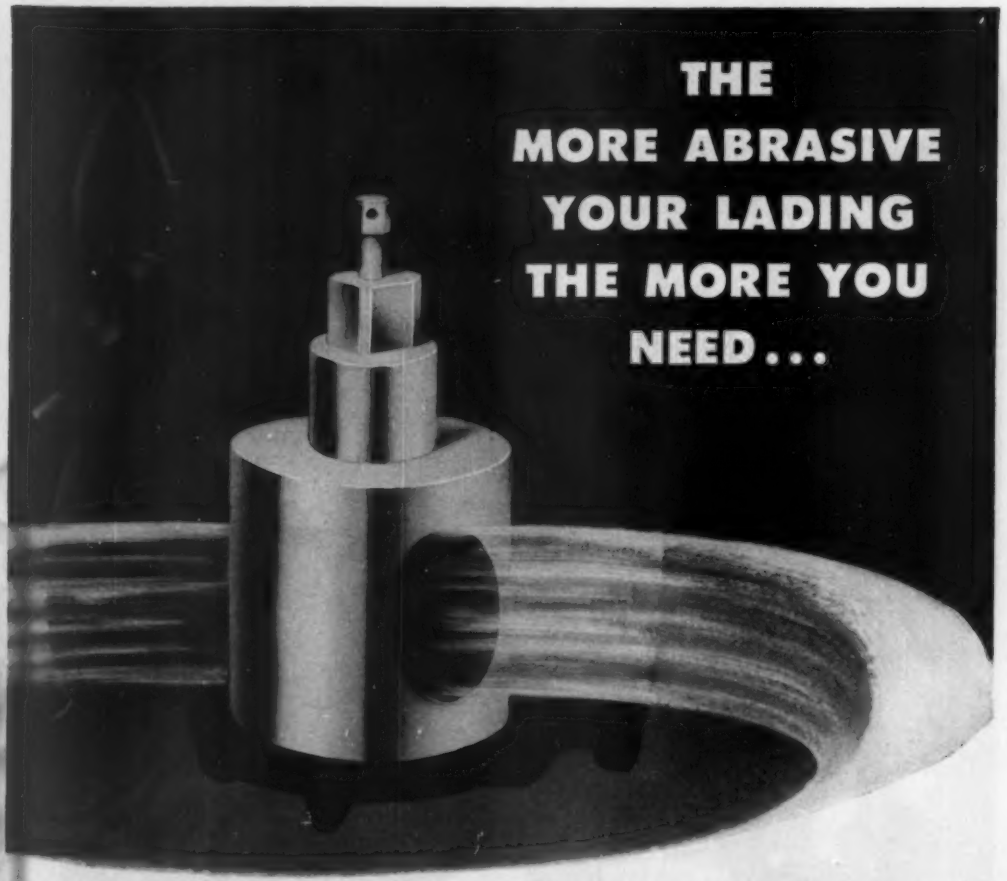
The recent expansion and improvement in Danville's water treating system necessitated extensive changes and additions, all of which were carried to completion without interrupting service from the existing plant. The new construction project, affecting every phase of the plant from the intake at the Dan River to the Bellow Park Reservoir, brings plant rated capacity up to 9 MGD. In the new water treatment plant, as specified by the engineers, Chas. T. Main, Inc., Omega Feeders are utilized for adding the chemicals required to control taste, odor, and pH of final effluent. The new feeders were installed by V. B. Higgins Co. under the joint direction of Howard A. Johnson, Supt. of Water Treatment; E. M. Hawkins, Jr., Manager of the Water, Gas and Electric Departments; and L. R. McClung, Supt. of Water Distribution. For Bulletins describing Omega equipment, address Omega Machine Company (Division of Builders Iron Foundry), Providence 1, R. I.

Omega equipment furnished for the Danville Water Treatment Plant:

3—Model UF-1 Universal Feeders (1-alum, 1-soda ash, 1-hydrated lime). Feeding rates: 5 to 200# per hr. Extension hoppers with high and low level controls, dust collectors, high speed mixers, and dissolving chambers with float boxes.

1—Model RL-7 Rotolatk Feeder for feeding carbon at rates from 1 to 100# per hr. Extension hopper, dust collector, high speed mixer, and dissolving chamber with float switch.

THE LAST WORD IN FEEDERS
OMEGA



a.c.f. cylindrical plug valves

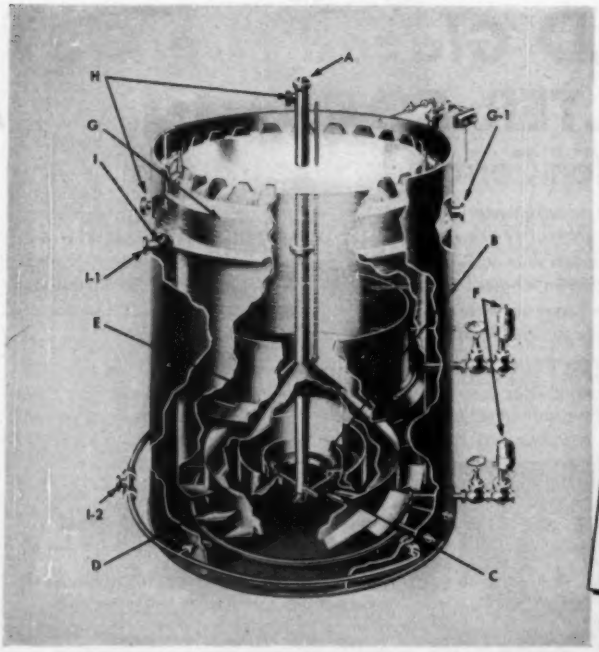
They alone provide the full-pipe-area passage, and straight-through round* porting, that can banish abrasion troubles. Lubricant-sealed from contact with the lading, the precision-machined plug does not wear or need attention, other than an occasional turn of the lubricating screw. Why use less efficient valves?

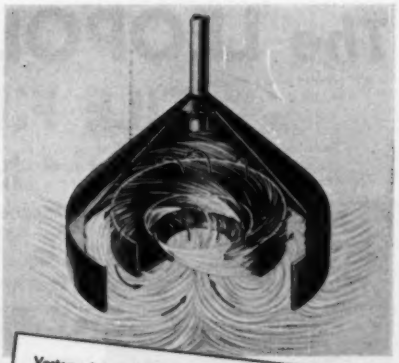
*Also available with full-pipe-area rectangular port.

a.c.f. CYLINDRICAL FULL PIPE AREA LUBRICATED **PLUG VALVES**

Representatives in more than 50 principal cities

Write for Catalog 4-WS describing types and sizes, to: American Car and Foundry Company, Valve Division, 30 Church Street, New York 8, N. Y.





Vortex mixing eliminates need for submerged moving parts in the Worthington Cold Process Slurry Type Precipitation Water Softener and Coagulator.

REACTION TANK of Worthington Slurry Type Softener (Slurry bed eliminated for clarity). (A) Raw water influent line. (B) Vortexor for optimum slurry production. (C) Chemical Applicators. (D) Slurry bed rotator. (E) Symmetrical Slurry concentrator. (F) Proportionate sludge removal. (G) Collector trough for treated water. (G-1) Treated water effluent. (H) Complementary recirculation. (I) Filter wash water compartment. (I-1) Filter wash water suction. (I-2) Filter wash water return.

This slurry bed stays put!

. . . and troublesome variables are out

These Features Give You The Uniformity You Want

WORTHINGTON SLURRY TYPE PRECIPITATING WATER SOFTENER AND COAGULATOR gives consistent, uniformly softened water

If it's clear, uniformly softened water you want, this unique Worthington Water Softener is just what you need. Concentrated quick mixing and rapid recirculation of applied chemicals and raw water, *achieved by hydraulic energy instead of submerged mechanical moving parts*, is an important, progressive development in the water treatment field.

New Bulletin W-212-B5 gives you 16 pages of vital facts about this unique cold process water softening method. Write for your free copy today.

REMEMBER . . .

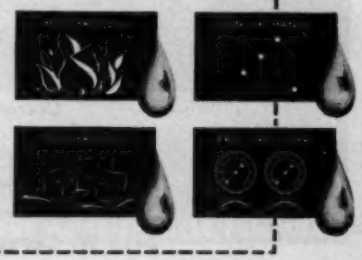
Worthington engineers *all four* water conditioning processes; therefore, can give you unbiased recommendations on which process is right for you . . . further proof that *there's more worth in Worthington. Worthington Pump and Machinery Corporation, Water Treating Division, Harrison, N. J.*

20.1

WORTHINGTON

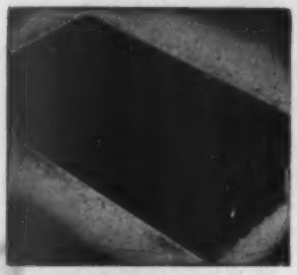
WATER CONDITIONING

Worthington Makes More of the Equipment for All Types of Water Conditioning Systems



The LEOPOLD Glazed Fire Clay TILE FILTER BOTTOM

Permanent • Non-Corrosive • Economical



Standard Filter Block

Designed to completely eliminate the many difficulties previously experienced with underdrain systems, the Leopold Duplex Filter Bottom has proven entirely successful in well over 100 municipal and private purification plants. Produced from de-aired fire clay—vitrified and salt glazed, this unique filter bottom is impervious to attack by acid or alkali solutions, won't absorb any detrimental amount of water, and will last a lifetime.

The Leopold Filter Bottom is composed of separate blocks, each covering 2 square feet of filter floor and weighing approximately fifty pounds per square foot. These individual blocks are set level and firmly joined together, thus forming a strong bed that is not disturbed by wash water. The Leopold Duplex System assures a positive and equal collection of filtered water, reduces loss of head, and makes possible reduction of pipe and valve sizes.

CHECK THESE FEATURES OF THE LEOPOLD FILTER BOTTOM

- The laterals and distributing blocks are all combined in one unit.
- Blocks are made from high grade de-aired fire clay, vitrified and carefully salt glazed so that they're practically non-absorbent.
- System is always kept in sanitary condition with no corrosion or tuberculation anywhere in the filter bottom.
- The filter bed is divided into sections of about 2 square feet. This insures equal filtration, also equal distribution of wash water over entire bed.
- With this design, only a shallow depth of the smaller sizes of filter gravel are required.
- Loss of head is extremely low as the head is just sufficient to insure equal distribution when filtering and back washing.
- Readily adaptable to any rectangular filter units.
- Blocks are combined into one heavy, strong unit.
- Life of this filter bottom is extremely long.
- Highly efficient performance in well over 100 purification plants.

Complete Filter Bottom Showing Wash Water Distribution

Literature and complete details on request!

F. B. LEOPOLD CO., INC.

Water Purification and Sewage Plant Equipment

2413 W. Carson Street **Pittsburgh 4, Pa.**

SELECTED IN

1944

BECAUSE OF

Reliability and Efficiency

and

STILL PROVING IT IN

1950

DECATUR, ILLINOIS chose ACCELATORS in 1944 for their water treating plant . . installed to help serve war industries. ACCELATOR was selected because of its *remarkable performance record in over 1100 installations from coast to coast* which treat ONE BILLION *Gallons of water every day!* Simplicity of design, sturdy construction, so few movable and mechanical parts, were added considerations that won Decatur's approval. Today, *in 1950,* its reliability and operating efficiency is still being proven day after day!

Pictured below is the Decatur installation, consisting of 2 ACCELATORS, each 54 feet in diameter. Together, they can economically soften and clarify 12 MGD. Lake Decatur water is treated . . the Lake formed by damming the Sangamon River. Turbidity after treatment averages 2.0 PPM, usually less!

If treating water or waste is a subject of interest to you, by all means send for our new 28-page bulletin No. 1825. Learn how ACCELATOR can . . 1. Save up to 80% in space, 2. Give simpler operation, 3. Faster chemical reaction, 4. Higher ratings, 5. An exclusive slurry recirculating feature which produces better, clearer water in less time. Let our competent engineers help you with your problems. No obligation. Write today.

ACCELATOR®

INFILCO

* BETTER WATER CONDITIONING AND WASTE TREATMENT SINCE 1894 *

INFILCO INC.

GENERAL OFFICES [illegible]

SALES OFFICES IN TWENTY SIX PRINCIPAL CITIES

WORLD'S LEADING MANUFACTURERS OF WATER CONDITIONING AND WASTE TREATING EQUIPMENT

Arrowhead Grating is made to fit the job, eliminating the waste and expense of field cutting. All pieces are punched and bolts furnished to make a one piece floor or walkway when installed.

Arrowhead Grating is comfortable and quiet to walk and work upon since the pattern provides bars extending in every direction.

Arrowhead Treads are designed to include a definite slip proof nosing that will not become distorted even under extremely heavy use.

ARROWHEAD IRON WORKS

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North Kansas City 16, Mo.
Phone NOrclay 3121

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Houston 20, Texas
Phone: Charter 4129

Write for our catalog.

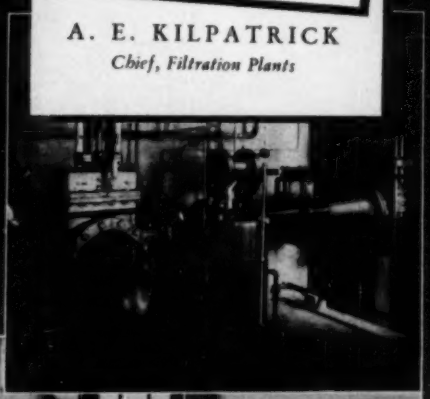
MONTREAL, CANADA

Rapid Sand Filtration Plant

C. J. DES BAILLETS
Chief Engineer

F. Y. DORRANCE
Engineer in Charge

A. E. KILPATRICK
Chief, Filtration Plants



For more than a generation Montreal has maintained its enviable reputation for low cost production of high quality water, despite increased pollution of the raw water supply. The original plant having 16 filters, with a capacity of 50 million gallons daily, was placed in service in 1911. Three extensions, each of the same capacity, have since been added — the latest in 1945 built by the Atlas Construction Co., Ltd., Montreal, and Roberts Filter Co. of Canada, Ltd., Toronto. Builders Venturi Filter Effluent Controllers with Master Control were selected for the initial plant, and proved so satisfactory that all extensions were similarly equipped. For Bulletins describing Builders water works equipment, address Builders-Providence, Inc., (Division of Builders Iron Foundry), Providence 1, R. I.

Builders water works equipment furnished Montreal Filtration Plant:

- **20" Venturi Effluent Rate Controllers**
- **Filter Loss of Head, Rate of Flow Gauges**
- **Master Control Filter Rate Setting Units**
- **Portable Sand Expansion Indicators**
- **Venturi Meter with Chronoflo Telemeter Totalizer — Indicator — Recorder for Wash Water**
- **Automatic Sluice Gate Positioners to Control Level in Various Channels**

BUILDERS — PROVIDENCE
Instruments

NEWPORT NEWS MECHANICAL RACK RAKE

WATER users troubled with trash are invited to write for new descriptive rack rake catalog.

THE Newport News Mechanical Rack Rake is a power-operated rake for cleaning trash racks at water intakes for hydroelectric plants, steam plants, pumping stations, canals and similar installations. It cleans the rack bars of trash and reduces a former major hand operation to one of minor periodic activity. With Newport News Mechanical Rack Rake installations, one man per shift can, under ordinary conditions, keep the racks clean for a dozen bays.

NEWPORT NEWS SHIPBUILDING AND DRY DOCK COMPANY

NEWPORT NEWS, VIRGINIA

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the *NEW* COLEMAN AC pH METER

offering Coleman precision . . . plus line operating convenience

- **DIRECT READING** . . . Dual scale meter calibrated 0-8 and 6-14 for continuous, direct reading of pH or millivolts. One switch for scale selection.
- **ACCURATE** . . . to 0.05 pH with proper technique. Unaffected by line voltage variations . . . fully protected from moisture and humidity.
- **FAST** . . . Instant reading . . . just flip the switch and the needle indicates the exact pH or millivolts. No annoying creep or oscillation.
- **STABLE** . . . Complete Stability 5 minutes after starting. Settings remain constant and reproducible over long periods without resetting or restandardizing.
- **CONVENIENT** . . . Easy-to-operate—Easy-to-read well protects the electrodes when not in use. The black plastic case is stain and corrosion proof.

Write today for Bulletin FB-221 for a full description of this New Coleman contribution to laboratory accuracy.

COLEMAN INSTRUMENTS *famous first* . . . . . pH ELECTROMETERS · ELECTRONIC PHOTOFLUOROMETERS · CHEMISTS' SPECTROPHOTOMETERS · PHOTO NEPHELOMETERS · ANOXIA PHOTOMETERS

318 MADISON STREET, MAYWOOD, ILLINOIS

Tegul-MINERALEAD* and HYDE-RO RINGS

An efficient way to join Cast Iron Bell and Spigot Pipe

The use of HYDE-RO RINGS with TEGUL-MINERALEAD is recommended by Atlas for best results. These two jointing materials are easy and clean to work with, economical, and require no skilled labor. For complete details on these two Atlas products, write us at 20 Walnut Street, Mertztown, Penna., requesting Bulletins No. M10-1 and M10-5.

Suppliers of G-K, the original hot poured bituminous Sewer Joint Compound, and ATLASTIC 77, ready mixed cold trowel type Sewer Joint Compound. Special bulletins available upon request.

THE ATLAS MINERAL PRODUCTS COMPANY

MERTZTOWN, PENNA. HOUSTON, TEXAS

*Trade Mark Registered

Save... MAN-POWER

With DRACCO PNEUMATIC CONVEYORS

The following Chemicals are efficiently and economically handled by DRACCO Pneumatic Conveyors in Water Works and Sewage Treatment Plants located in all parts of the country. Alum, lime soda ash, bauxite, ferrous sulphate, pebble lime, activated carbon, and ammonium sulphate.

A PARTIAL LIST OF *DRACCO* INSTALLATIONS

FRIDLEY FILTRATION PLANT	Minneapolis, Minn.
DALECARLIA FILTRATION PLANT	Washington, D.C.
MUNICIPAL WATER SOFTENING PLANT	Sandusky, Ohio
MUNICIPAL WATER SOFTENING PLANT	Ames, Iowa
LEMIEUX ISLAND FILTRATION PLANT	Ottawa, Ontario
MAHONING VALLEY SANITARY DISTRICT	Niles, Ohio
MUNICIPAL WATER PLANT	Columbus, Ohio
MUNICIPAL WATER PLANT	Peru, Ill.
U. S. GOVERNMENT FILTRATION PLANT	Ft. Leavenworth, Kans.
MUNICIPAL WATER PLANT	Hamilton, Ohio
BACHMAN WATER PURIFICATION PLANT	Dallas, Texas
MUNICIPAL WATER PLANT	Richmond, Va.
MUNICIPAL WATER PLANT	Springfield, Ill.
MINNEAPOLIS-ST. PAUL SANITARY DISTRICT (Sewage Disposal Plant, 2 installations)	St. Paul, Minn.
MUNICIPAL WATER PLANT (2 installations)	Milwaukee, Wis.
MUNICIPAL SEWAGE DISPOSAL PLANT	Oklahoma City, Okla.
MUNICIPAL SEWAGE DISPOSAL PLANT	Denver, Colorado
MUNICIPAL WATER PLANT	Covington, Ky.
MUNICIPAL WATER PLANT	Ann Arbor, Mich.
CLAYTON SEWAGE DISPOSAL PLANT	Atlanta, Ga.
SEWAGE DISPOSAL PLANT (2 installations)	Cleveland, Ohio
MUNICIPAL WATER PLANT	Benton Harbor, Mich.
MUNICIPAL WATER PLANT	Warren, Ohio
MUNICIPAL SEWAGE DISPOSAL PLANT	Detroit, Mich.
MUNICIPAL WATER PLANT	Flint, Mich.
CITY OF TORONTO WATER WORKS PLANT	Toronto, Ontario
WATER FILTRATION PLANT	Ottawa, Kansas
EL RENO WATER TREATMENT PLANT	El Reno, Oklahoma
CITY OF GRAND FORKS	Grand Forks, North Dakota
MUNICIPAL SEWAGE PLANT	Pittsburgh, Pennsylvania
WATER FILTRATION PLANT	Wichita, Kansas
INDIANAPOLIS WATER CO.	Indianapolis, Ind.
WATER FILTRATION PLANT	Appleton, Wis.
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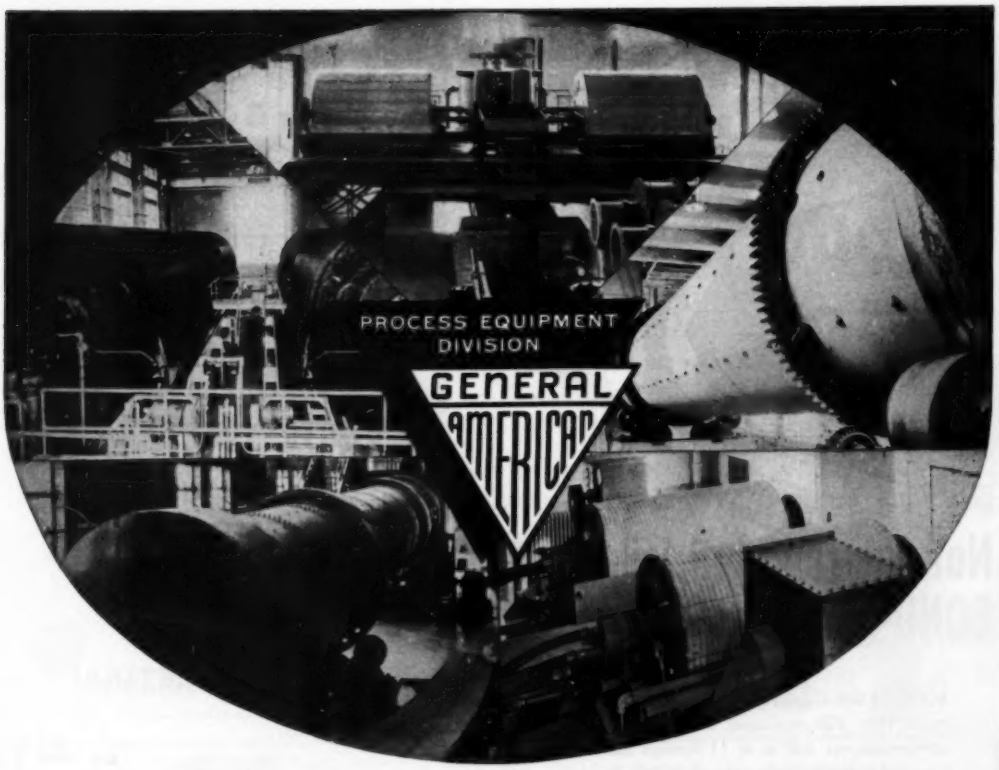
Write for Bulletin No. 526

DRACCO CORPORATION

4079 E. 116th St., Cleveland 5, O. • New York Office, 130 W. 42nd St.

PNEUMATIC CONVEYORS • DUST COLLECTORS



Modern Sewage Treatment Plants

require equipment that has proved itself efficient and is backed by individual responsibility for design, engineering, fabrication and initial operation.

General American Conkey Sludge Filters—the first to be used for large scale dewatering of sludges such as primary, elutriated-digested, Guggenheim Process, etc.—are dewatering more than a thousand tons of dry solids daily.

General American Louisville Dryers have been successfully used for years drying both activated and digested sludges. Type "L", with patented fire-conduits to eliminate scorching or burning, produces a uniformly high quality maximum yield of dried product for fertilizer or earth conditioner.

Let the experience and knowledge of General American engineers help you while your plans are in the blue print stage.

OTHER GENERAL AMERICAN EQUIPMENT

SLUDGE DRYERS	TURBO-MIXERS	THICKENERS
SLUDGE GASHOLDERS	STORAGE TANKS	SCREENING DEWATERERS

GENERAL AMERICAN TRANSPORTATION CORPORATION

Process Equipment Division

SALES OFFICE: 10 East 40th St., Dept. 830C, New York 17, N. Y.

WORKS: Sharon, Pa., East Chicago, Ind.

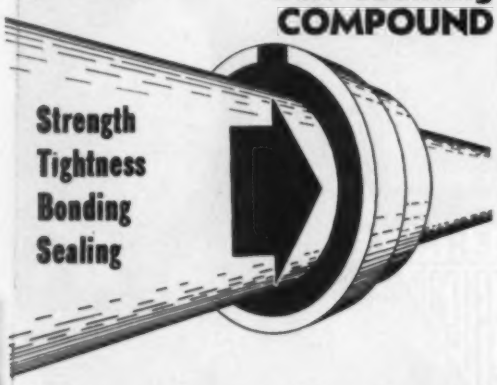
TRADE MARK

OFFICES: Chicago, Cleveland, Louisville, Orlando, Pittsburgh, St. Louis, Sharon, Washington, D. C.

BOND-O

Homogenized

Self-Caulking COMPOUND



Not one reported failure of BOND-O Jointing Compound!

BOND-O Self-Caulking Compound is in use by more than 600 municipal and private water companies—as well as in 11 foreign countries . . . and not one single case of BOND-O jointing failure has ever been reported.

BOND-O is homogenized. BOND-O's unique machine blending process gives you uniformity of performance—uniformity of strength—uniformity of tightness—uniformity of bonding—and uniformity of sealing.

Sulphur, carbon, iron, silica, right down the line—only the best and purest ingredients are used.

BOND-O's selection of these basic materials and exclusive machine blending process are your assurances that BOND-O joints will give you the same service that you expect and receive from the good cast iron pipe on which it is used.

For what other jointing compound can such claims be made?

BOND-O

NORTHROP & COMPANY, INC.
SPRING VALLEY, NEW YORK

IF . . .

PUMPING INDUSTRIAL WASTES

IS YOUR HEADACHE—

SEND FOR THESE BULLETINS!

Bull. #419
"Sumps for 'VS' Pumps"

Bull. #400
"Pumping Solids"

(Shows Penna. approved construction)

THE MOST VERSATILE LINE OF HORIZONTAL & VERTICAL PUMPS AVAILABLE . . . .

BARRETT, HAENTJENS & CO.
HAZLETON, PA.

Pittsburgh, Penna. — Birmingham, Ala.
Huntington, W. Va. — Phoenix, Arizona

LABORATORY-TESTED *HOURLY!*

Gold Bond

HYDRATED AND QUICK **LIME**

Simplify your water purification problems
with one of these TESTED lime products.
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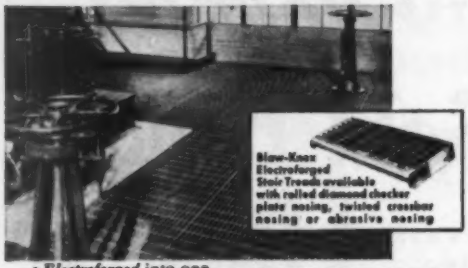

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APPLY TO BOTH SINGLE AND DOUBLE STRAP CLAMPS

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Precision gauged—meets recognized thread standards

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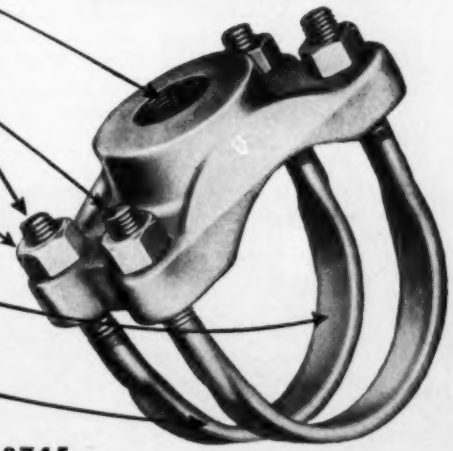
Threading performed *after* strap bending, assuring no forging distortion or "burn". Threads and straps *then* heavily cadmium plated

LARGE CADMIUM PLATED NUTS!
Plated *inside* and *out*

***FLATTENED STRAPS!**
Gives wider bearing surface—more friction—eliminates loosening of clamp that occurs with round straps

ACCURATE CURVATURES!
Engineered to fit any type of pipe



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DEPENDABLE SINCE 1857 FULLY WARRANTED OUR 93rd YEAR

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Bulletin on POROUS MEDIA by CARBORUNDUM

TRADE MARK

NO. 9 MAY, 1950

Porous Disc Underdrains for Smaller Softeners and De-Ionizers

In rapid filters and large softeners, ALOXITE aluminum-oxide underdrain plates are already used extensively. The reasons are obvious—these plates eliminate graded gravel, with all its costly difficulties—and they permanently protect the media.

This success with large installations has focused attention on the possibility of using similar material for smaller-capacity units. Such material is available in the form of ALOXITE porous discs.

Applied to smaller de-ionizers and softeners, these porous discs permit the use of more exchange material in a given-size pressure shell. As a result, longer runs are possible. Or, in a new installation, the height of the shell can be decreased for the same amount of exchange material. In actual practice, the user will ordinarily gain the most by keeping to the full-size shell, using more media and taking advantage of the longer runs.

Properties of ALOXITE Porous Media

MATERIAL	Ceramically bonded crystalline aluminum oxide grain of controlled sizes.
GRADES (Pore Size)	Filter Underdrains... coarse and very coarse. Direct Filtration... range from very fine to medium. Diatomite Support... range from fine to medium. Air (gas) Diffusion... range from fine to coarse (permeability from 10 to 120).
SOLUBILITY	In Water and Air... insoluble at all normal operating temperatures. In Acids... generally resistant at all operating temperatures, except to hydrofluoric acid. In Alkaline Solutions... ceramic bonds are progressively soluble with time and temperature increases.
STRENGTH	Transverse breaking strength is relatively good ranging from 1000 lbs./sq. in. (coarse grades) to 3000 lbs./sq. in. (fine grades).
REFRACTORINESS	All grades withstand up to 900° C. without softening.
THERMAL SHOCK RESISTANCE	Withstand changes up to 20° C./hr. (Where more severe heat shock exists, ceramically bonded silicon carbide porous media are available.)
POROSITY	Ratio of pore volume to total volume of all grades approximately 35%.
WEIGHT	Approximately 0.09 lbs./cu. in.

"Carborundum" and "Aloxite" are registered trademarks which indicate manufacture by The Carborundum Company

POROUS BOTTOM TRICKLES...

Ion-exchange and softener units, of the design shown below, are offered as standard equipment by Wilson Engineering Company, Little Rock, Arkansas. The porous underdrain disc is indicated in color in this drawing.

Several other well-known softener and de-ionizer manufacturers can supply units using ALOXITE disc underdrains. These follow a similar split-shell construction.

A number of users report that they save time in the initial charging of units which use porous underdrain discs. Zeolite or ion-exchange material is simply dumped into the shell after assembly. Careful placing of support gravel and media is unnecessary.

TECHNICAL DATA

on porous media and their application is available on request. You may obtain any or all of the following engineering bulletins by writing Dept. M-50.

No. 1 — Aeration of Sewage and Water.
No. 2 — Underdrain Systems for Filters and Softeners.
No. 3 — General Catalog information.

THE CARBORUNDUM COMPANY
Refractories Division
PERTH AMBOY, NEW JERSEY

EVEN THE SMALL COMMUNITY CAN HAVE A MODERN SEWAGE TREATMENT PLANT PROTECTED BY BYERS WROUGHT IRON

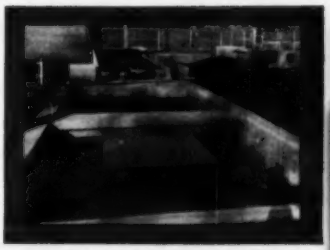
Small in size but completely modern in every detail, the new Webster-Crestwood Sewage Treatment Plant, St. Louis County, Missouri, was developed and is owned by Russell & Company, Inc., operating engineers. It serves portions of Webster Groves, Crestwood, and a section of St. Louis County, Missouri. The ultimate design is to handle sanitary flow from 1400 acres. The present plant is flexible in design and construction and can be expanded as the requirements demand. Russell & Company, Inc. made extensive use of wrought iron in the various "hot spots" where severe corrosion is always encountered. Byers Wrought Iron pipe was used in sludge pump piping and return pump piping. Byers Wrought Iron hot rolled material was utilized in the weir plates; diversion gates, and run-off channel gates.

You can't get away from corrosion in any sewage treatment plant —but you can keep corrosion from getting away from you, and loading the installation with back-breaking maintenance and repair expense. Wrought iron has been used in practically all of the trouble-spots in modern plants, and has proven its superior corrosion-resistance many times over. You'll find it profitable to investigate the record it has made, as a guide in your own construction and maintenance work.

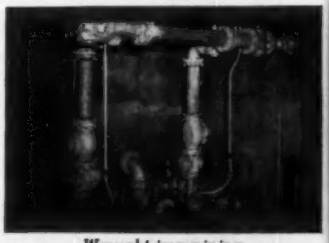
The reason why wrought iron has made such an unusual showing is found in its unusual composition and structure. Tiny fibers of glass-like silicate slag, threaded through the body of high-purity iron halt and disperse corrosive attack. This discourages the pitting and rapid penetration that generally causes premature failures in vulnerable materials. The fibers also help to anchor the initial protective scale, which shields the underlying metal.

You will find some helpful information on the use of wrought iron in sewage plants in our bulletin, WROUGHT IRON FOR SEWAGE TREATMENT AND DISPOSAL INSTALLATIONS. If you have a problem in connection with some particular service, we will be glad to supply a report of user experience with wrought iron under similar conditions.

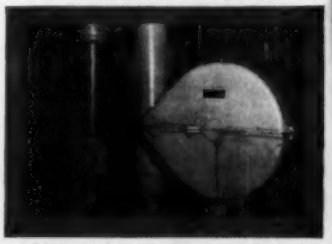
A. M. Byers Company, Pittsburgh, Pa. Established 1864. Boston, New York, Philadelphia, Washington, Atlanta, Chicago, St. Louis, Houston, Salt Lake City, San Francisco. Export Division: New York, N. Y.



Wrought iron weir plates



Wrought iron piping to intermediate return pumps



Wrought iron sludge pump piping

CORROSION COSTS YOU MORE THAN WROUGHT IRON

BYERS
GENUINE WROUGHT IRON
TUBULAR AND HOT ROLLED PRODUCTS

EST. 1856
McDonald

McDONALD CRAFTSMANSHIP
in waterworks brass

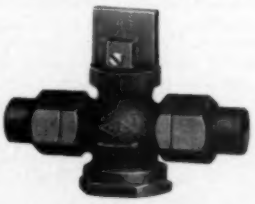
E-4721
Solid brass tee handle curb stop. Inlet copper pipe, outlet iron pipe thread.

McDonald "Diamond Line" curb and corporation stops are smooth in operation, dependable in service. They are precision made from 85-5-5-5 metals with every step from foundry to final inspection and testing under rigid control. Ground keys fit close for perfect sealing, yet turn easily for trouble-free servicing... clean threads mean easier, faster installation...full waterways assure maximum flow.

For real economy in waterworks brass, for items designed to stay on the job and keep maintenance costs low, specify McDonald—for 94 years only the best. Write for literature and prices.

E-4717
Minneapolis pattern curb stop. Both ends copper pipe couplings. Now furnished with combined cap and tee handle.

E-4701
Corporation Stop.



E-4713
Combined cap and tee handle inverted key curb stop for copper pipe, both ends.

E-4727
Curb Stop for copper service pipe. Minneapolis pattern. Solid brass tee handle.

E-4711
Combined cap and tee handle inverted key curb stop. Inlet copper pipe, outlet iron pipe thread.

A. Y. McDONALD MFG. CO.
DUBUQUE, IOWA
BRASS GOODS • PUMPS • OIL EQUIPMENT

HYDRO-TITE

WHEN YOU WENT COURTING...

A pair of "Bull Dogs" like these and a three-inch starched collar were standard equipment. Probably a sailor straw with a gaily striped band rounded out the ensemble.

Even back in those days HYDRO-TITE was doing its job of making joints in cast iron water mains that were being laid away for keeps.

Styles have changed but HYDRO-TITE is still doing its job. Those joints are right there serving you twenty-four hours a day.

HYDRO-TITE is still made in powder form packed in 100-lb. moisture-proof bags, and now is obtainable also in "LITTLE-PIG" solid form in 50-lb. cartons.

Let HYDRO-TITE go to work for *you*.

PROTECT YOUR MAINS BY USING
FIBREX
THE BACTERIA FREE JOINT PACKING.

HYDRO-TITE AND FIBREX IN STOCK IN

Portland, Oregon	Seattle, Wash.
Kansas City, Mo.	Memphis, Tenn.
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HYDRAULIC DEVELOPMENT CORP.

MAIN SALES OFFICE **50 CHURCH ST., N. Y. C.**

General offices and works **W. Medford Sta., Boston, Mass.**

they ask ROBERTS FILTER

again and again and again!

As the years go by and water supply expansions are necessary, ROBERTS FILTER is invariably called back to take care of the additional requirements. Listed below are but a few of the clients that we have been pleased to serve again and again.

- City of Charlotte, North Carolina
- City of Montreal, Canada
- E. I. Du Pont de Nemours & Co.
- City of Lynchburg, Virginia
- City of San Juan, Puerto Rico
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- City of Newport News, Virginia
- Proximity Mfg. Co.—Greensboro, N. C.
- City of Tonawanda, New York
- City of Edmonton, Alberta, Canada
- City of Barranquilla, Colombia
- City of Gadsden, Alabama
- City of Athens, Greece
- City of New Iberia, Louisiana
- City of Fayetteville, North Carolina
- City of York, Pennsylvania

• GRAVITY & PRESSURE FILTERS • FILTRATION PLANT SPECIALTIES
• WATER TREATMENT EQUIPMENT • RECIRCULATION APPARATUS

MECHANICAL EQUIPMENT BY ROBERTS FILTER MFG. CO. DARBY, PENNA.

ROBERTS FILTER MANUFACTURING CO.
607 COLUMBIA AVE., DARBY, PENNA.

In thousands of municipal and industrial water systems

CALGON* prevents lime scale

Calgon*

PREVENTS LIME SCALE

*T.M. Reg. U.S. Pat. Off.

HAGAN HALL BUROMIN CALGON

calgon, inc.

HAGAN BUILDING PITTSBURGH 30, PA.

For detailed information, including a list of typical applications, send for this bulletin. Just fill in and mail the coupon.

*T. M. Reg. U. S. Pat. Off.

CALGON, INC.
HAGAN BUILDING
PITTSBURGH 30, PA.

Please send me your bulletin, "Calgon Prevents Lime Scale."

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Company_____

Street and Number_____

City_____ Zone____ State_____

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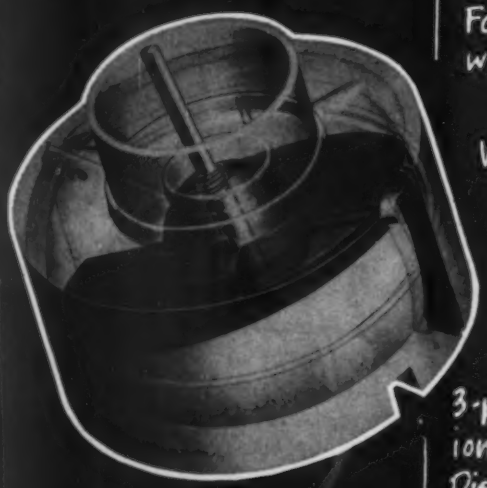
Why TRIDENT Meters COST LESS and GIVE YOU THE MOST REVENUE!

③ DISC CHAMBER AND DISC



DESIGNED

For accuracy, protection against wear, breakage.

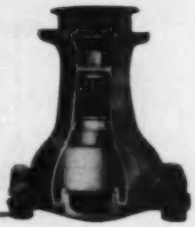
CONSTRUCTED

With Sand Ring – 3-part Disc with Thrust Roller-Renewable Thrust Roller Bearing Plate.

RESULTS

Long life. Sustained accuracy, Sand ring excludes grit etc., 3-part Disc permits compensation for wear, Thrust Roller prevents Disc breakage. Renewable roller bearing plate takes wear from Chamber, quiets operation.

THE measuring chamber is the heart of the Trident Meter. That's why it is so carefully made, so essentially simple, so well protected...a triumph of experienced Neptune design and construction—the principal reason why you can't beat Trident Water Meters for maximum revenue and minimum maintenance cost.



New improved parts in old Trident Meter

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Branch Offices in Chicago, San Francisco, Los Angeles, Portland, Ore., Denver, Dallas, Kansas City, Louisville, Atlanta, Boston.
NEPTUNE METERS, LTD., Long Branch, Ont., Canada

WATER & SEWAGE WORKS

Vol. 97, No. 5 May, 1950

A Gillette Publication

SPARTANBURG'S WATER WORKS

A Story of 30 Years of Progress and Expansion Under a Superintendent With Vision and Support of a Far-sighted Commission

by

H. F. WIEDEMAN
WIEDEMAN & SINGLETON, ENGINEERS
ATLANTA, GA.

THIRTY years ago the Commissioners of Public Works of Spartanburg, South Carolina, employed a new Water Superintendent to assume charge of their water system which was then inadequate and obsolete. During the years which followed the system grew and was made over into a modern and efficient plant, with an average daily water use many times that required in 1920. Spartanburg's system not only has kept pace with requirements during the years since, but has always been a few steps ahead. In all these years there was never a water shortage and sufficient water of adequate quality has always been available to fulfill domestic and industrial requirements—in fact, enough to permit special summer sprinkling rates and encouragement of the public to maintain beautiful lawns and gardens.

Bronze Plaque Commemorating Plant Dedication
"In Recognition of the Outstanding Vision and Service of Superintendent R. B. Simms."

On June 29, 1949, the Commissioners of Public Works officially named the Water Filtration Plant the "R. B. Simms Filtration Plant" in recognition of this superintendent's outstanding service, and his contribution to the growth, health and recreational facilities of his city. The Commissioners decreed that a commemorative plaque be placed at the plant to record their action. On May 11, 1950, the plaque pictured in this article was unveiled with appropriate ceremonies. Interestingly,

the principal address was made by a former water works operator who served as Chemist in Charge of the old Filtration Plant of Spartanburg during World War I—Linn Harrison Enslow, Editor of *Water and Sewage Works* Magazine, and immediate past-president of the American Water Works Ass'n.

The story of Spartanburg's water system is an interesting exemplification of the faith of a man in the future of his city, and his ability to get things done which he felt necessary to make the growth and development of his city possible.

Water Supply in 1920

The water supply of Spartanburg in 1920 when Mr. Simms took charge was obtained from several creeks near the city and was treated in a plant consisting of a sedimentation basin, dug out of the hillside during World War I, and wood-tub filters. Water was discharged into an open clear water well from which it was pumped into the system by two steam driven cross-compound engines.

Flat rates were charged all customers and average water use was 2,000,000 gallons daily. Installation of meters was promptly started, and by 1922 water use had decreased to 1,500,000 gallons daily. Thereafter water use turned upward and continued to increase, reaching 2,000,000 gallons per day by 1924. The 1920 population of 22,638 had risen to 25,000 in 1924.

In 1924 an engineering study was made which indicated that the existing supply must soon be abandoned because of inadequacy and the encroachment of industry and homes on the water shed and that the future supply should be obtained from the South Pacolet River, about twelve miles from Spartanburg.

The Author

Announcement by the Southern Railroad Co. that they proposed to construct large shops and a housing development on the drainage area of the existing supply resulted in the decision to start construction of the new South Pacolet supply at once.

The South Pacolet River:

The South Pacolet River, which was selected as the source of the new water supply, rises in the foothills of the Blue Ridge Mountains at an elevation of 2,000 feet above sea level, and rapidly descends to an elevation of 1,000 feet, which is the general level of the plateau. It flows in a southeasterly direction to its junction with the North Pacolet River to form the Pacolet River, which is tributary to the Broad River of the Carolinas. At least 35% of its entire drainage area of 120 square miles is rugged mountainous country and the balance of the area consists of farms and forests. The topography of the South Pacolet's drainage area is such that there is little possibility of future industrial development. Since the North Pacolet River carries the sewage of a number of towns and textile mills on its drainage area, and conditions in this section are favorable for further industrial growth, it was decided to locate the intake on the South Pacolet River immediately above the junction of the two streams.

The rainfall conditions in the drainage area are particularly interesting because rainfall in the mountainous section generally exceeds 60 inches per year while the rainfall in the Pied-

Old Filtration Plant and Pumping Station of Spartanburg
Operated by Ye Ed. During World War I and Inherited by Supt. Simms—1920.

mont Plateau area is less than 50 inches.

Initial Development of South Pacolet Supply:

At the point selected for the development of the supply the river passed thru a narrow rocky gorge and over shoals. If a dam 50 feet in height were constructed at the head of the shoals water would not only flow to the filtration plant by gravity, thus eliminating low-lift pumping, but there would be a total head of 63 feet available for the production of hydro-electric power. The reservoir created by the dam would impound one and a quarter billion gallons, 900,000,000 of which would be available in the upper 15 feet. Under average rainfall conditions, the production of 4,000,000 KW hours of energy could be expected, of which 1,500,000 KW hours would be required the first year for pumping and other plant use. Further inquiry indicated that all excess power could be sold to an electric utility system operating in this area.

A reinforced concrete dam was constructed at the point indicated and water was conveyed to the power house located about 1,200 feet downstream from the dam thru a 78-inch steel penstock, from which water is also taken for the filtration plant.

The power house was equipped with two 750 HP Francis Turbines direct connected to two 625 KVA, 2300 volt generators. High lift pumping equipment consisting of three 4 mgd. motor driven centrifugal pumps were installed in the power house. Switch-

Supt. Robert B. Simms

boards were installed so that power could be drawn from or delivered to the power company line; or, if desired, part of the power generated could be delivered to the pumps and the balance to the power company line.

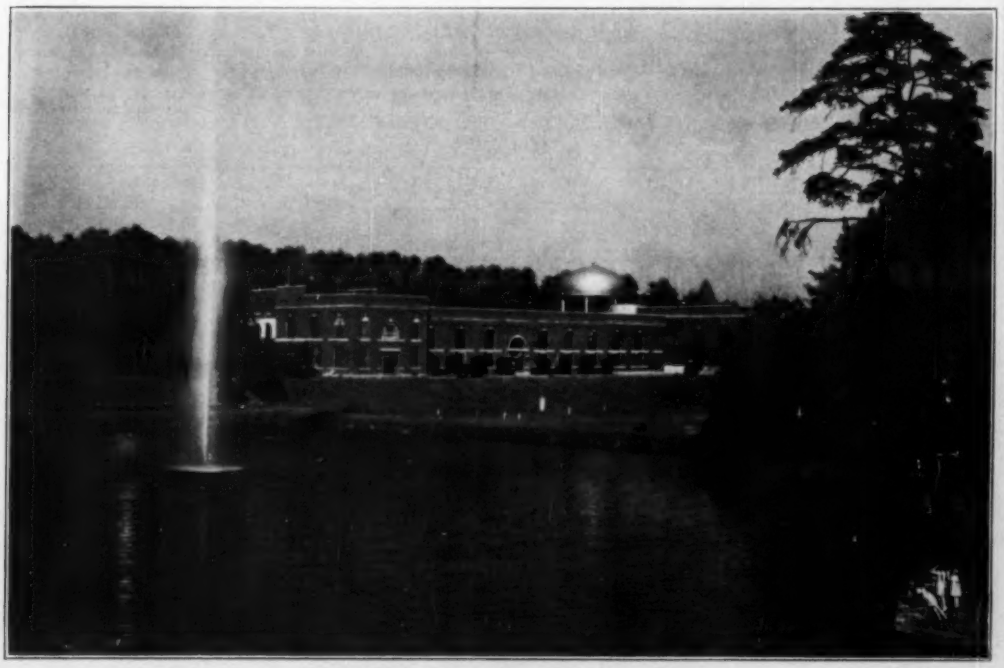
The filtration plant consisted of two mixing and sedimentation basins and six one million gallon capacity filters discharging into a 750,000 gallon clear water well.

The high service pumps, located in the power house, discharged water through a 24-inch cast iron supply line about 15,000 feet long to a 3,000,000 gallon reinforced concrete tank for the finished water. From this tank the water flows by gravity thru a 70 centimeter 27.56 in. cast-iron pipe line to the city, where proper distribution pressure is maintained by a pressure regulating valve.

In order to provide more uniform service pressures and flow at consumers' taps, to prevent wide fluctuations in the supply line, and to provide large volumes of water for fire purposes, a 1,500,000 gallon elevated tank was constructed approximately at the center of the distribution system.

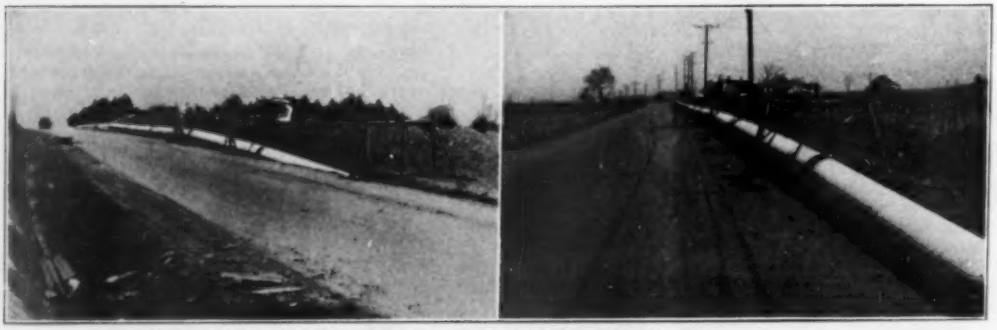
Growth and Plant Additions

By 1939 the average daily load for the year had increased to 4.6 million gallons and daily consumption for the maximum month increased to 5.8 million gallons. Plant additions in that year consisted of an additional sedi-



The 11 MGD R. B. Simms Filter Plant at Spartanburg

Looking Across "Rainbow Lake" at the Modern Plant Now Undergoing Fourth Enlargement Since 1926.



Two Construction Views of the 40,000 ft. 24" Steel Pipe Line
Spiral Weld Wrapped Pipe Jointed with Dresser Couplings.

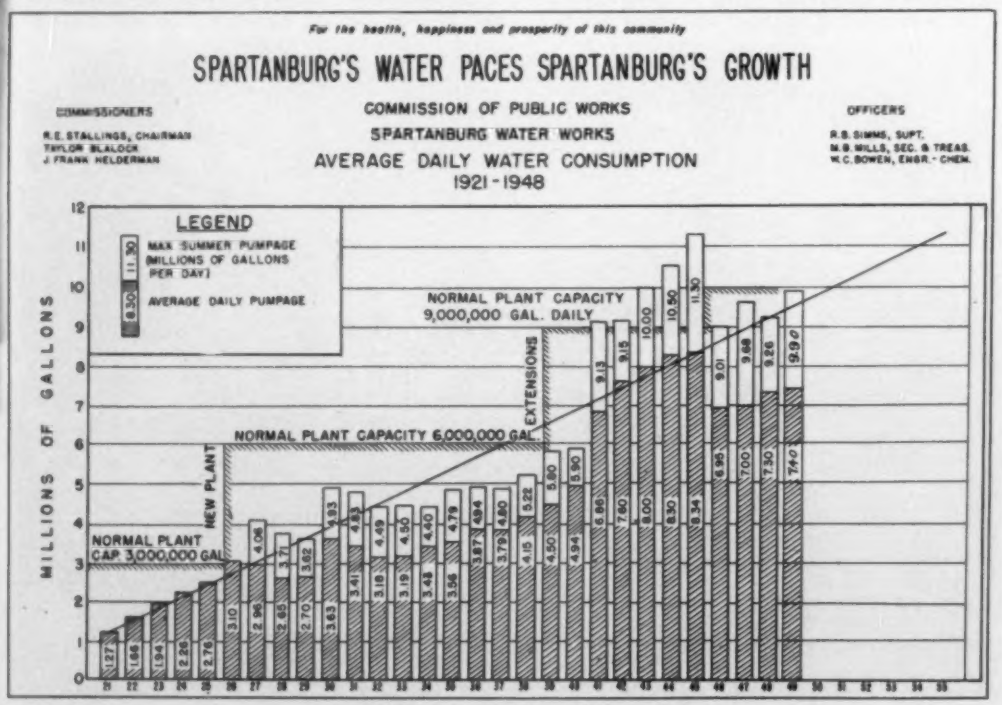
mentation basin and mixer and a 3 mgd. capacity filter arranged to wash in two sections, an additional five million gallon pump, a 20-inch diameter steel discharge line to the high level reservoir and a 24-inch gravity line of spiral welded steel to the distribution system. This line is protected with a spun bituminous enamel lining and is bituminous coated and wrapped with asbestos felt.

There was now a normal filtration capacity of 9,000,000 gallons daily, while the gravity supply lines had a capacity to deliver 15.4 million gallons daily to the top of the 1.5 mg. elevated tank in the city.

Under normal conditions this increase in capacity would have been sufficient for a considerable period in the future, but war activities at Camp Croft and additional domestic and industrial demands increased the average daily consumption for the year 1942 to an average of 7.7 million gallons daily, while the maximum daily output reached better than 10 million gallons in August, 1943. The peak of war consumption was reached in 1945 with an average use for that year of 8.3 million gallons daily and a maximum day of 11.3 million.

The conclusion of the war and the abandonment of Camp Croft reduced water use in 1946 by an average of approximately 1.4 million gallons daily below that of 1945. However, in the following year this trend was reversed, and it became evident that by the end of 1950 maximum daily demand would again exceed normal plant capacity. To meet this anticipated demand plans were prepared in 1947 for again extending the plant.

These extensions, upon which con-



Growth Chart of the Spartanburg Water Supply
Showing an Interesting History Between the Two World Wars, Necessitating Two Increases in Plant Capacity Since 1926.

struction is now nearing completion, consist of a 3,000,000 gallon capacity steel ground-storage tank which is located adjacent to the 3,000,000 gallon reinforced concrete storage tank constructed in 1925, and operates in parallel with it.

At the filtration plant, a new mixing chamber and sedimentation basin have been constructed and new control equipment has been added. Raw water enters the control room thru a 30-inch pipe and a rate controller. The rate setting on the controller may be changed from a point convenient for the operator. Alum, lime or soda ash and chlorine may then be introduced before the water reaches a flash mixer. After 30 seconds of flash mixing the water is divided, part flowing to the three existing sedimentation basins and part to the new basin. Flow to the new basin passes thru a 36-inch line equipped with a meter and a hydraulic control valve by which the rate of flow to the basin is regulated.

The lower floor of the control house is arranged to store and handle one-ton containers of chlorine and the chlorination equipment is located directly above the chlorine storage. Chlorination facilities are being improved and a residual recorder has been added.

The new mixing basin is of the gravity type and provides 30-minutes retention at three million gallons daily rate. Considerable difficulty has been experienced in the operation of sedimentation basins by deposition of settled material at the inlet end of the basins, causing the basins to be cleaned more often than desirable. In the new basin the first 20 feet is equipped with sludge removal mechanisms which will eliminate this difficulty. The new sedimentation basin is so arranged that additional basins may be added as needed.

"Hello! Mr. Simms"
Characteristic of the Esteem for Their Water Supt. and Benefactor Was This Greeting from 3 yr. Old Sandra Holland, Enjoying the New "Rainbow Lake" Pool at the Filter Plant.

Additional filters may also be added as needed but will not be constructed at this time because experience has demonstrated that, with pre-chlorination, proper chemical application, improved mixing and settling, filters may safely be operated at rates in excess of two gallons per square foot per minute. The present filters are arranged in single bank but the new units when constructed will be in double bank. The existing filters are being modernized by being equipped with surface wash.

Hydro-Electric Plant Profitable

Conditions were extremely favorable for the construction of the hydro-electric plant in connection with the filtration and pumping plant. In the initial phase of the operation only a small amount of the available power was required in plant operation, the balance being sold at the power house switchboard. Power could also be obtained from the power company in emergencies and the capacity of connecting lines was such that speed control was simplified.

The power produced became more valuable to the city, as the quantity used for pumping increased, and the power plant which cost $350,000 when constructed was fully amortized in twenty years.

Raising the river level eliminated all low lift pumping, and stream regulation due to the use of storage also made it possible to divert up to an average of 10 million gallons daily from the stream without damage to industrial power plants operating on the river below the site. There are no transmission lines and the plant is operated and maintained by the usual filter plant personnel.

Looking from the Filter Plant Across "Rainbow Lake." Enjoyed by Thousands of "Spartans"
The Swimming Pool and Boat House Are at Far End. Picnic Grounds Are Beyond.

"Guardian Sentinel"
Spartanburg's 1.5 M.G. (R. D. Cole) Elevated Tank Is Located Very Near to the Center of the Distribution System.

Some Comparisons of Spartanburg Water Works
June 30, 1920 vs. June 30, 1949

	June 30, 1920	June 30, 1949
Plant Value	$468,244.19	$3,664,488.68
Indebtedness	273,502.88	988,000.00
Water Pumped		
Gals. per Year	463,550,000	2,699,387,000
Avg. Gals per Day	1,270,000	7,398,300
Total Income	$129,984.90	$ 345,006.64
Total Oper. Exp.	87,484.90	249,329.82

Charges for Water Sold on a Sliding Scale Basis
June 30, 1920 vs. June 30, 1949

	June 30, 1920	June 30, 1949
Residences or Small Water Consumers	50c per 1000 gal.	25c per 1000 gal.
Large Water Consumers	15c per 1000 gal.	8.5c per 1000 gal.

Note: Sliding Scale Rate based on quantity of water used, applies to all consumers alike.

	1920	1950
Water Mains Inside the City (Mains outside the city, laid by private interests, not listed)	50 mi.	218 mi.
Fire Hydrants Inside City, and on city property	241	817
Fire Hydrants Outside City, set by private interests	None	411
Metered Services	2250	11,100

Power is sold on a "dump-power" basis at a comparatively low rate, while it must be purchased by the city at the published commercial rate. The value of power generated computed upon the commercial rate for power used in pumping, and at the "dump-power" rate for the power sold was $63,210 for 1949. Recent inspection of the hydro-plant indicates that no major repairs or replacements are necessary and that the plant will continue to operate satisfactorily for many more years.

To avoid possible damage claims for water diversion from the stream, plans have been prepared for raising the height of the dam and increasing storage capacity if and when this becomes necessary.

Development of Recreational Facilities:

The area in which the plant is located comprises about 200 acres of land admirably suited for park purposes. A part of the area has been allocated to the homes and gardens of the plant operators and about 70 acres have been developed into a beautiful park of tree shaded slopes with picnic pavilions and a large swimming pool in a natural setting, complete with diving towers, life guards and all the conveniences and sanitary safeguards of the modern pool. This pool is known far and wide as Spartanburg's "Rainbow Lake." Here the citizens of Spartanburg and their guests are free to enjoy swimming or other recreational facilities in a clean wholesome atmosphere. As many as 5,000 persons have enjoyed these facilities in one day. The concessions at the pool pay the cost of operation, but by far the most important return upon the investment is measured in terms of improved public relations which has resulted.

Water Sales to Industry:

Spartanburg is a textile center and the water system serves a number of textile mills. One of these mills, using between one and two million gallons daily, takes water on an "off-peak" basis. This arrangement results in operating economy for the water works system and earns a reduced water rate for the mills. This bit of economy has been made possible by constructing a five million gallon reservoir at the mill and operating the feed line to the mill only during the night hours, or at other periods when water use in the city is at a reduced rate.

Public Relations Policy:

The policy of the Commissioners of Public Works has always been to keep the public of Spartanburg fully informed as to its operations by interim advertisements in the press, showing the financial condition of the system, and by the distribution of folders, pamphlets and press releases showing load increases and the reasons for proposed plant extensions. As a result, the public has become water conscious and the Commission and its superintendent enjoy full public support in their operations. It may also be observed from the data here presented that water rates in Spartanburg have been cut approximately in half during the Simms regime and period of expansion and modernization of Spartanburg's water supply facilities. All the while the water department has continued to make a profit.

The New Supplemental 3,000,000 Gal. Ground Storage Tank
Just Completed by Chicago Bridge & Iron Co.

ALKALINITY SIGNIFICANCE IN SEWAGE OXIDATION*

The Second of a Series of Articles

by

W. W. ECKENFELDER, JR.
Cons. San. Chemist

JOHN W. HOOD
Superintendent

SEWAGE TREATMENT WORKS
RIDGEWOOD, N.J.

IT IS generally accepted that varying degrees of oxidative treatment are attained by the different types of biological treatment plants. To date, however, no simple, direct and reliable method of appraisal has been available to the sanitary field. For example, the 5-day B.O.D. is generally accepted as an indication of the degree of treatment accomplished. Actually this determination does not distinguish between the various physical and biological processes involved and the results obtained are generally confined to the carbonaceous component.[1]

On the other hand, it emerges that a simple, direct, and dependable determination such as the alkalinity, may be used as a criterion to disclose, in addition to the degree of oxidative treatment performed, the chemical changes in the substrate occurring in and through the carbonaceous and nitrogenous stages of treatment. This is extremely important since the purification and clarification of sewage is a function of several physical and chemical mechanisms which together produce an effluent of the required quality.

The solid components of settleable size are removed by mechanical separation in sedimentation units. The colloidal fraction and the soluble components are removed in secondary treatment processes by adsorption and flocculation, absorption, oxidation and reduction and agglomeration. In order to reliably determine the efficiency of a treatment process, the influence of each phenomenon associated with the process should be evaluated on a relative basis. This has been done in this work using oxidation as the basis for treatment consideration. *The assumption is made that in order to obtain a bacteriologically stable effluent some oxidation of the readily decomposable organic material must occur and that the ultimate stability of that effluent will be a direct function of the extent to which this oxidation has occurred.*

The Authors
W. W. Eckenfelder, Jr. J. W. Hood

Oxidation may be distinguished from physical phenomena in that a direct transformation occurs with respect to the components of the solution yielding constituents of different chemical and physical characteristics, while adsorption, flocculation, etc., remove material from the sewage without exacting a direct change in the composition of the solution. An aqueous solution may have undergone clarification by adsorption and still contain putrescible organics in solution which may prove to be obnoxious upon being discharged. In this respect the Methylene Blue Stability test would provide a convenient index.

From this primary consideration of sewage and waste treatment, those units which tend toward complete oxidation will produce the most stable effluents and those which do not tend toward oxidation will produce the least stable effluents. This does not embrace truly anaerobic processes such as digestion.

Alkalinity:

The alkalinity in sewage consists of mineral and organic materials. The mineral portion of the alkalinity is derived from the water supply and the organic alkalinity is derived from domestic wastes.

[The determination of alkalinity is made by employing the exceedingly simple tritation with N/50 sulphuric acid, using methyl orange as indicator. The method is that given in "Standard Methods for Water & Sewage Analysis" for

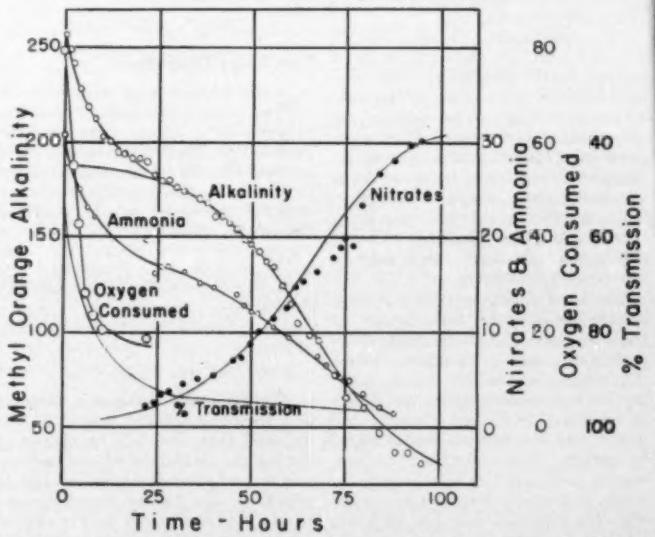


Fig. 1—Summer Oxidation of Domestic Sewage by Aeration and the Changes in Chemical Character of Substrate with Respect to Time

*Condensed by the authors from their original paper presented before the New Jersey Sewage Works Association meeting in March 1950.

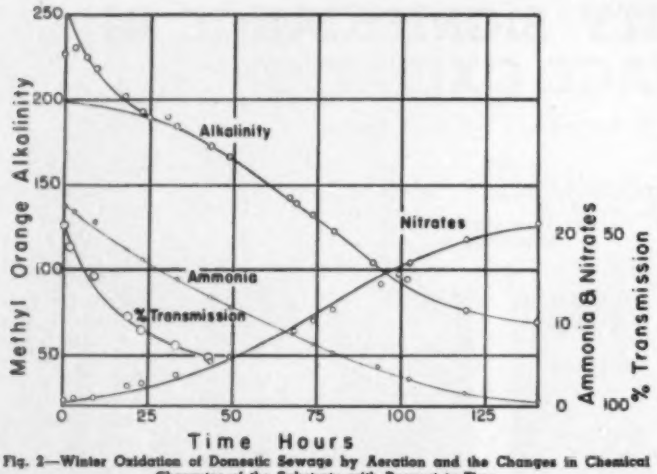


Fig. 2—Winter Oxidation of Domestic Sewage by Aeration and the Changes in Chemical Character of the Substrate with Respect to Time

determination of alkalinity of waters. Only a few minutes is required to perform the test. When gross solids appear in the sample these are allowed to settle out during a brief period before decanting the sample.—Ed.]

It has been noted by some investigators [3] [4], that the buffer value of a sewage changed as that sewage underwent oxidation. In 1946 Hood[4] showed that treatment efficiency was qualitatively indicated by changes in the pH and the alkalinity of the substrate.

The studies reported here were conducted in an effort to establish criteria of treatment which distinguished between the active purification mechanisms and to yield a more practical and fundamental method of operational control.

The relationships established in this paper are considered in terms of the oxidizable alkalinity. This may be defined as that portion of the total alkalinity which can be removed by an oxidative mechanism. Since some portion of the total alkalinity is inorganic, there will be a residual alkalinity after complete oxidation. This portion must be subtracted from the original alkalinity value to obtain that alkalinity which may be removed by oxidation.

The total alkalinity of the sewage may be considered to be composed of basic organics and the mineral bicarbonates and carbonates. When this sewage is oxidized biologically, the carbonaceous organic alkalinity is oxidized to carbon dioxide and water, and the ammonia is oxidized to nitrates. The oxidation of the ammonia will yield acidic nitrous or nitric acid which immediately reacts with the inorganic alkaline buffer to produce neutral salts of the metal and nitrate ions present.

For Example

(1) $2NH_3$ (aqueous) $+ 3O_2 = 2\ HNO_2 + 2H_2O$

Then

$2HNO_2 + Ca\ (HCO_3)_2 = Ca\ (NO_2)_2 + H_2CO_3$

The carbonate or bicarbonate alkalinity will be reduced below that value initially present in the water by the reaction between the acidic nitrate or nitrite and the basic carbonate or bicarbonate. Hence, for complete oxidation, the net resulting alkalinity will be that residual after complete oxidation of the ammonia nitrogen to nitrates. This residual alkalinity may be approximately computed to be the inorganic alkalinity of the water less the total oxidizable nitrogen x 1.79.

$$A_r = A_w - (N_o \times 1.79)$$

First Stage Oxidation:

In the first stage of oxidation the carbonaceous compounds present are progressively acted upon by the micro-organisms to eventually yield carbon dioxide as an end product. In terms of oxidation this first stage may be expressed by the equation $A = A_o t^{-k}$.

Where—

A = Oxidizable Methyl Orange Alkalinity.

A_o = Total Oxidizable Alkalinity at t = o.

k = Constant.

The ammonia nitrogen is likewise progressively reduced, and it may be deduced that the fall in alkalinity during the oxidation of the carbonaceous components of the sewage, is primarily due to the metabolic assimilation of nitrogen by the organisms active in the oxidation process. Considering the carbonaceous compounds, the alkalinity decrease may be indicative of (a) initially the hydrolysis of the organics and the agglomeration of colloidal material such as soaps and high molecular weight organics and the absorption of basic salts from solution and (b) the decomposition of sugars, proteins, protein derivations, etc., yielding fatty acids which forms salts in solution.

The loss in alkalinity in the carbonaceous stage of oxidation may be considered to be a product of the metabolism of the organisms active in the oxidation. A lag period may be present, induced by the lag phase in the growth rate of the organisms. The alkalinity likewise is reduced in proportion to the reduction in the oxygen consumed revealing that the reduction in alkalinity in the carbonaceous oxidation stage is a function of the degree to which this oxidation has occurred with respect to the metabolic activities of the micro-organisms involved. When the oxidation of the carbon compounds is essentially complete, the organisms die off and their cells are broken down giving the ammonia back to the substrate to be oxidized to nitrates in the second stage oxidation.

Turbidity:

The change in turbidity of sewage as oxidation proceeds is noted to be related to the changes in alkalinity. Colloidal material constitutes the major portion of the oxygen consuming carbonaceous organics. Results as indicated in this paper are based upon the light transmission through the sample using distilled water as a base of 100% transmission. From this relation it may be deduced that the initial phase reduction of alkalinity is largely a function of the removal and oxidation of acid consuming organic colloids.

Second Stage Oxidation:

The reduction in alkalinity due to the second stage oxidation is primarily a function of the oxidation of ammonia to nitrates.

The ammonia content of the sewage will vary as the stage of decomposition of that sewage and will be a primary determining factor in the alkalinity and hence the buffer value exerted by the sewage. The alkalinity of the raw sewage or the effluent from primary tanks will be a function of the degree of decomposition which has occurred in the sewage. If anaerobic conditions become pronounced, the ammonia will increase, due to hydrolysis of urea and result in a net increase in the buffer

value. Biological oxidation will reduce the ammonia through its bacterial assimilation in the oxidation of the carbonaceous material, this process reducing the net buffer value. The further oxidation of the ammonia will finally result in mineral forms and a buffer value less than that of the carriage water without organic pollution.

The second stage oxidation curve may be expressed by the relation

$$A=(A'_o - A)_e \cdot K'A'_o(t-c)$$

Where:

A=oxidizable alkalinity at any time t

A'o=total nitrogenous oxidizable alkalinity at t=o

k'=velocity constant

c=t/2 for the total nitrogenous oxidation

The above relations are all based upon the oxidizable alkalinity. Figures 1 and 2 illustrate the relation of alkalinity with respect to time during the aeration of sewage. The differences in the curves (variation in A'o and k') are due to the variation in the temperature, the variable food supply, etc.

The variations in ammonia, nitrate nitrogen and nitrite nitrogen were determined in conjunction with the changes in alkalinity. These are illustrated under summer and winter conditions on Figs. 1 and 2. The ammonia nitrogen curve followed the same general pattern as the alkalinity curve. The initial drop in ammonia may be attributed to adsorption phenomena and to the removal of colloidal form ammonia. When nitrification started, the nitrite formation increased and the ammonia nitrogen decreased. The subsequent conversion of nitrite to nitrate was noted after nitrification had progressed. Toward the end of the nitrification stage, the solution developed a characteristic yellow color.

It appears from the experiments conducted in this study that the nitrification started almost immediately and that some nitrogen oxidation occurred simultaneously with the carbon oxidation although the principal utilization of ammonia in this stage was for the metabolic needs of the carbonaceous micro-organisms. It may be deduced that no clear cut distinction exists between the carbonaceous and the nitrogenous stages but that the former does take precedence over the other with respect to time.

In the absence of basic carbonates only ammonium carbonate is oxidized while in the presence of basic carbonates other forms of ammonia will be oxidized. Since sewage is

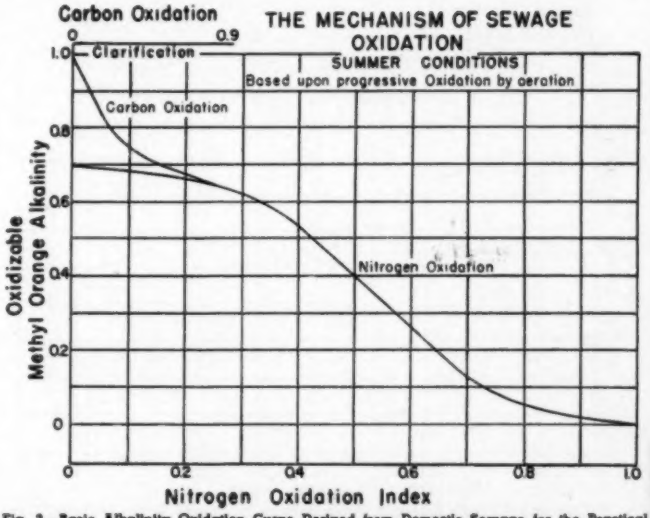


Fig. 3—Basic Alkalinity Oxidation Curve Derived from Domestic Sewage for the Practical Approximation of Oxidative Plant Performance

(The oxidation index values are in per cent expressed as a decimal; when multiplied by 100 they represent the per cent of the total time required for complete oxidation.)

usually buffered with these basic salts, optimum ammonia oxidation will proceed from most forms in the pH range 7.0 to 8.0.

Discussion:

A simplified example of how alkalinity reduction occurs as oxidation proceeds is shown below.

The influent contains carbohydrates and NH_3 as NH_4HCO_3. First stage oxidation would reduce the ammonia concentration by bacterial assimilation in the oxidation of the carbohydrate. The carbohydrate would be oxidized to organic acids, CO_2 and H_2O.

(a) (NH_4HCO_3) effluent $<$ (NH_4HCO_3) influent

(b) $(C_xH_yO_z)_x$ influent $=$ (X) $(COOH) + H_2O$

The result would be a reduced buffer value in terms of pH-alkalinity. At this point the auto-catalytic curve of nitrogen oxidation is found in which the alkalinity falls off rapidly and there is a reduction in pH. The alkaline compounds react with the nitrite formed and are neutralized. Further oxidation will yield nitrates.

The simplified reaction for this may be considered:

$$M^+_2 + CO_3^= + 2HNO_2 \rightarrow M^+ + NO_2^- + CO_2 + H_2O$$

When nitrification is complete and the sewage reduced to end products (CO_2, H_2O, NO_3, etc.) the alkalinity will reach a minimal value, the pH at this point will be established by the CO_2 and the still remaining alkaline and acidic compounds.

The above examples are hypothetical with respect to the complex composition of domestic sewage. In addition to the above possible reactions, many others are occurring simultaneously and either increase or decrease the buffer value. Nitrogen deficient material during the first stage of decomposition, results in the formation of various organic acids. If further treatment, temperature, etc., favor a more complete degradation, a change in reaction to a more alkaline condition occurs due to the formation of carbon dioxide and carbonates. This alkalinity is neutralized by the formation of nitrates in second stage oxidation.

Fatty acids may be formed from poly- and mono-saccharides or from proteins and protein derivatives, usually by anaerobic or facultative bacteria. When these are neutralized as might generally occur in sewage, they serve as sources of energy to bacteria. The decomposition of salts of these acids yields alkali carbonates which give an alkaline reaction to the medium.

Application:

The principles outlined in the foregoing text may be applied to biological sewage purification processes, and stream studies with certain modifications dictated by the process in question.

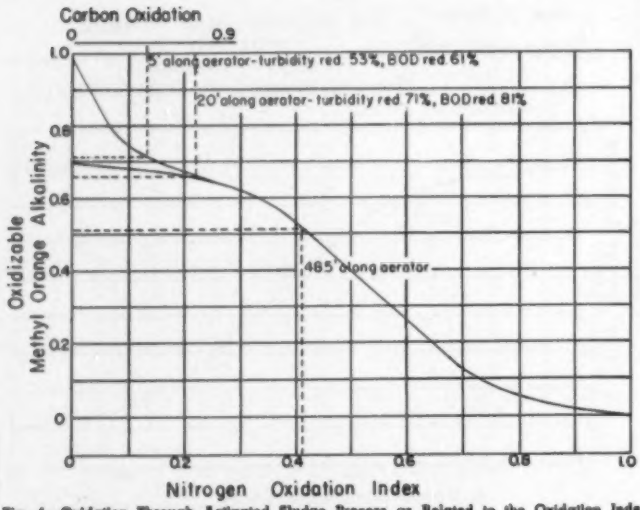


Fig. 4—Oxidation Through Activated Sludge Process as Related to the Oxidation Index Curve

(The oxidation index values are in per cent expressed as a decimal; when multiplied by 100 they represent the per cent of the total time required for complete oxidation.)

A method has been devised to make practical application of the theory of the foregoing text to sewage plant operating data for the approximate measurement of the degree of oxidation accomplished. Direct application of the principles and formulations to biological oxidation plant units is impossible because the theory is derived from a progressive oxidation of domestic sewage by plain aeration. The zoogleal film and the biologically active matrix of the trickling filter and the activated sludge processes respectively introduce modifications in the basic formulations derived from plain aeration studies such as transformations in the substrate induced by withdrawal of component parts of the substrate by the biologically active medium.

This method consists of applying plant process data to the mean basic progressive oxidation curve of normal domestic sewage. The indices obtained for carbon and nitrogen oxidation portrays the plant performance relative to an equivalent degree of oxidation accomplished by aeration with respect to time. Since the use of this method is based upon the oxidizable alkalinity the inorganic residual alkalinity must be obtained and subtracted from the total titrated alkalinity. The calculation of the residual alkalinity which will still be present after theoretical complete oxidation (assuming the net sum of the components at the start were equal to the net sum of the components at the finish) has been effected involves a more extensive analysis than most plants are equipped to perform. For a practical approximation this residual may be computed as the alkalinity of the water supply less 40 ppm. for a normal domestic sewage. The 40 ppm. which represents that portion of the inorganic alkalinity which will be neutralized by acid formation in the course of oxidation is a function of the alkaline ammoniacal components which are present to be oxidized. This 40 ppm. must be increased in the case of a particularly strong or concentrated sewage (high total N) and decreased in the case of a weak or dilute sewage (low total N).

The determination of these indices with the use of Fig. 3 may best be illustrated by an example:

Given the following data it is desired to find the oxidation indices of a process.

Raw sewage alkalinity=250 ppm.; treated effluent alkalinity=150 ppm; water supply alkalinity= 90 ppm.

The sewage is of medium strength.

Oxidizable alkalinity of raw sewage equals 250—(90-40)=200

Oxidizable alkalinity of effluent equals 150—(90-40)=100

Per cent oxidizable alkalinity remaining in effluent equals
100/200=0.5 × 100=50

From Fig. 3. Carbon Oxidation Index=0.9+ and Nitrogen Oxidation Index=0.42.

These indices may be interpreted to mean (assuming no losses in the system) that if the sewage had undergone progressive oxidation the carbon oxidation would be 90+ per cent complete with respect to time and the nitrogen oxidation would be 42 per cent complete with respect to time.

This method is only an approximation since variations in the character of the sewage, temperature, etc., will produce a variation in the oxidation curve and the biological process being investigated may take out or put in oxidized or reduced componds to the substrate. However, to afford a plant operator a rapid and simple approximation of the oxidative performance of his process the methods outlined are deemed to be of sufficient accuracy with a straightforward interpretation.

Activated Sludge:

Considering the activated sludge process, the mechanisms of purification active in sewage aeration will be found in a more accelerated phase.

The mechanism of activated sludge probably involves physico-chemico, enzymic, biological, and biochemical phenomena. The transformations occurring in the activated sludge process would be analogous to that occurring in plain aeration, namely the removal of colloidal and dissolved constituents, hydrolyses and oxidation. Parsons and Wilson define the mechanism of activated sludge as occurring in three stages, namely (a) clarification, (b) reactivation or restoration of the powers of clarification, and (c) nitrification; (a) and (b) occur simultaneously. This was also noted as previously outlined in the sewage aeration studies. Clarification includes the removal of colloidal and suspended matter in addition to some removal from solution and usually results in some alkalinity reduction when these removed components are oxidized. The bulk of the biological work occurs during the second stage where the enzymes are produced and the slope of the alkalinity reduction curve greatest. When the clarification attained is purely physical there may be little or no alkalinity reduction.

Figure 4 depicts the changes in a sewage in contact with activated sludge through an aerator in terms of the Oxidation Index Curve.

Trickling Filters:

These principles as outlined may likewise be extended to biological filters of the oxidative or standard type. In this unit, reaction rates of chemical and physical nature are al-

tered. The nature of the changes in the chemical character of a sewage undergoing purification through a biological filter has been summarized by Levine [6] and other investigators.

As the sewage passes through the filter, it is continually modified in composition by the biological actions, so that at any point in the filter, the nature of the dissolved and other components, as well as the O-R-Potential of the medium, is different from that a short distance above or below. The alkalinity contributed by organic acid and basic compounds will vary and be reduced as oxidation proceeds. Therefore, in the upper portion of the filter, organisms predominate which are capable of attacking the proteins and amino acids with the liberation of such compounds as ammonia, hydrogen sulfide and acids from the decomposition of carbohydrates. In this layer the alkalinity may increase slightly. At an intermediate depth bacteria can activate these end products and oxidize them further. As the bottom of the filter is approached, the nitrifying bacteria (ammonia and nitrite oxidizing and the sulfur oxidizing) find a suitable biological environment, resulting in a rapid decrease in the alkalinity of the substrate.

Figure 5 depicts the changes in a sewage through the Ridgewood biological filtration plant in terms of the Oxidation Index Curve.

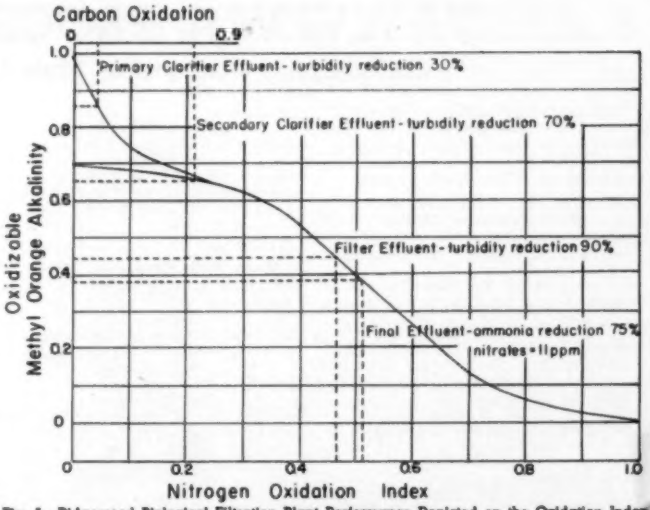


Fig. 5—Ridgewood Biological Filtration Plant Performance Depicted on the Oxidation Index Curve

(The oxidation index values are in per cent expressed as a decimal; when multiplied by 100 they represent the per cent of the total time required for complete oxidation.)

Table I

ACTIVATED SLUDGE PROCESS OPERATION

Sample	Rel. Stab.	pH	Alk. ppm.	Temp.	NH_3-N	Turb. ppm.
Raw Sewage	2%	7.07	190	23°C	11.5	56
5 ft. along aerator	22%	7.40	150		10.2	25
20 ft. " "	99%	7.46	143		9.85	16.75
48.5 ft. " "	99%	7.46	124		8.7	12
Clarifier effluent	99%	7.38	120		8.7	10.75

Table II

RIDGEWOOD BIOLOGICA'L FILTRATION PLANT

Sample	pH	Alk. ppm.	NH_3-N	Turb.	Temp.
Raw Sewage	7.70	255	31.4	64	22°C
Primary Clarifier Effluent	7.55	223	26.4	45	
Secondary Clarifier Effluent	7.35	174	20.6	19	
Filter Effluent	7.05	124	9.2	7	
Final Clarifier Effluent	7.00	114	8.0	5.3	

Summary and Conclusions:

Due to the inherent deficiencies in the B.O.D. test and the numerous environmental factors which affect the validity of the numerical values derived, it emerges that, as a criterion for design and process control purposes, it leaves much to be desired. It has also been demonstrated that while the B.O.D. yields quantitative values, it is incapable of conveying any accurate knowledge of the degree of oxidative treatment attained. For these reasons no consistent correlation between B.O.D. and alkalinity exists.

Alkalinity has been found to provide a reliable criterion of sewage oxidation which could be correlated with the important chemical changes in the substrate including the oxygen demand. The various stages of oxidation were determined in the sewage by alkalinity variation and related to the changes in turbidity, NH_3-N, NO_2-N and NO_3-N. From this investigation of the mechanism of biological sewage purification and its interpretation by alkalinity the following conclusions can be made:

1. The biological purification of sewage can be classified according to the mechanisms active in the purification process. These mechanisms and their relative magnitude with respect to each other will determine the chemical and biological character of the substrate.

2. The alkalinity, as indicated in this paper, will measure changes in the chemical character of the liquid and semi-liquid phase with respect to the formation or removal of alkaline or acidic compounds. Oxidation will usually lead to a progressively more acidic medium in a solution containing both carbonaceous and nitrogenous material.

3. A definite relation exists between alkalinity, ammonia, nitrite, nitrate, oxygen consumed and turbidity, with respect to time in sewage oxidation.

4. Biological sewage treatment processes may be classified and evaluated and facilities designed in terms of alkalinity and distinctions made as to the type and degree of treatment accomplished.

Acknowledgment:

Grateful acknowledgment is made to Mr. L. L. Langford for his sustained interest and substantial contribution to this work extending over the past ten years.

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A.W.W.A. PROGRAM

Philadelphia Convention, May 22-26, 1950

MONDAY, MAY 22ND—10:00 A.M.
Open Session

Committee on Water Works Administration
Committee on Water Works Practice

MONDAY, MAY 22ND—10:00 A.M.
Water Purification Division

Committee Reports:
Specification Tests for Water Purification Chemicals
J. E. Kerslake
Practical Loading Capacities of Water Treatment Plants
H. O. Hartung
Water Conditioning Methods to Inhibit Corrosion
K. W. Brown
Open-Air Reservoirs
N. J. Howard
Standard Methods for the Analysis of Water and Sewage
R. L. Derby
Panel Discussion:
Future Plans of the Water Purification Division

MONDAY, MAY 22ND—2:00 P.M.
Water Works Management Division

Panel Discussion:
Bill Collection Stations in Large Cities
Moderator—G. E. Arnold
Recording Customers' Use and Loss of Water
E. Arthur Bell
Studying Apartment House Water Demand
Edward Walasyk
Panel Discussion:
Management Experience with Metering Multiple Dwellings
Moderator—M. B. Cunningham

MONDAY, MAY 22ND—2:00 P.M.
Water Purification Division

Panel Discussion:
Operating Control of Small Treatment Plants
Moderator—L. D. Matter
J. N. Bartholomew C. R. Ridington
F. Gosnell R. G. Yaxley
Prevention of Settlement of Iron
C. R. Henry
Further Studies of Colorimetric Hardness Titration
J. D. Betz
Panel Discusion:
Experiences in Addition of Fluorides to Drinking Water
J. F. Kingsley L. A. Smith
J. C. Zufelt

TUESDAY, MAY 23RD—9:30 A.M.
General Session

One Hundred Fifty Years Water Works History
E. J. Taylor
Philadelphia's Plans for Water Supply Improvement
M. G. Mansfield
Development Plans for the Delaware River Incodel's Relationship to Present Plans
J. H. Allen
The 1950 Tri-State Report
Malcolm Pirnie
What the Plan Means to Penna.
F. S. Friel

TUESDAY, MAY 23RD—9:30 A.M.
Water Purification Division

Panel Discussion:
Controlling Aquatic Growths in Impounding Reservoirs
M. E. Flentje
Discussion
E. W. Furber
Further Studies of High Filtration Rates
J. R. Baylis
Possible Hazards Resulting from Chemical Contamination of Water Supplies
C. W. Muehlberger

TUESDAY, MAY 23RD—2:00 P.M.
Water Works Management Division

Pennsylvania's Experience with Water Authorities
F. S. Friel
Long Range Water Works Management as a Factor in Los Angeles Progress
S. B. Morris
Discussion:
Charles Haydock
How Can the Nation's Water Resources Be Developed in an Orderly Fashion?
G. F. White
Living With the Atom
N. R. Beers

WEDNESDAY, MAY 24TH—9:30 A.M.
Pipe Design

Design of Steel Plate Flanges
R. E. Barnard
Design of Prestressed Concrete Steel Cylinder Pipe
H. F. Kennison
Design Standards for Large Steel Water Pipe
W. H. Cates
Tests of Prestressed Concrete Steel Cylinder Pipe
F. E. Seaman
Performance of Coal Tar Enamel on Steel Water Pipe and Penstocks
G. E. Burnett

WEDNESDAY, MAY 24TH—9:30 A.M.
Water Resources and Purification Divisions

Adjustment of Water Treatment to Meet Loading Conditions
H. A. Faber
Discussion:
K. C. Armstrong E. B. Evans
D. B. Williams F. J. DeHooge
A. R. Todd B. L. Strother
Evaluating the Factors Contributing to Water Pollution
L. L. Hedgepeth
Pollution Controls versus Property Rights
J. H. Murdoch

WEDNESDAY, MAY 24TH—2:00 P.M.
General Session

Panel Discussion:
The Philosophy of Using Public Water Supply as a Means of Group Medication
A. P. Black H. T. Dean
J. L. T. Appleton
The Magnitude of Industrial Demands for Process Water
S. T. Powell
Treatment of Sea Water for Human Consumption
Discussion:
W. W. Aultman C. H. Spaulding

WEDNESDAY, MAY 24TH—2:00 P.M.
Water Resources Division

Committee Report:
Water Use Laws of the Various States
Richard Hazen
California's Water Pollution Control Laws
L. W. Grayson
A Review of Pending Water Resources Legislation in Congress
G. E. Ferguson
Report of Division Planning Committee
F. W. Kittrell

THURSDAY, MAY 25TH—9:30 A.M.
General Session

Panel Discussion:
Safe Yield From Surface Storage Reservoirs
Introduction
C. G. Paulsen W. B. Langbein
New England
G. W. Coffin
N.Y. Metropolitan
C. D. Livant E. J. Clark
New Jersey
C. H. Capen
Ohio Valley
C. B. Burdick
Arkansas
R. G. Kincaid
Summation
W. W. Brush

THURSDAY, MAY 25TH—2:00 P.M.
General Session

Public Fire Protection As A Factor In Rate Making
L. E. Ayres
Survey of Charges for Private Fire Protection
R. H. Ellis
Demand and Distance Factors in Rate Making
M. P. Hatcher
Panel Discussion:
Report of Committee on Water Rates
L. E. Ayres

THURSDAY, MAY 25TH—2:00 P.M.
Water Resources Division

Panel Discussion:
Prospecting for Ground Water
Geological Methods
R. M. Leggette
Geophysical Methods
C. A. Bays
Test Drilling
T. W. Thorpe
Pumping Tests
J. G. Ferris
Summation
J. J. Baffa
Recommended Procedure for Plugging Abandoned Wells—Preliminary Report of Committee
J. C. Harding

BUSINESS MEETING

FRIDAY, MAY 26TH—10:00 A.M.
Water Works Management Division

Committee Report:
Annual Report of Water Departments
M. P. Hatcher
What Does It Cost to Provide Service to Special Class Customers?
E. L. Bean
The Story of the Magnitude of Industrial Demands Upon the Chicago Water System
J. B. Eddy
Committee Report:
Water Use For Air Conditioning
F. C. Amsbary

GRAPHICAL APPROACH TO STATISTICS

Part I—The Nature of Variability of Data

by

C. J. VELZ
Professor and Chairman
Department of Public Health Statistics
SCHOOL OF PUBLIC HEALTH
UNIVERSITY OF MICHIGAN

The Author

SCIENCE and engineering today are all but buried beneath the mass of their own data. In fact, the mere accumulation of more and more data is too frequently regarded as research. Statistical evaluation offers the only means of condensing raw data to concise form, permitting significant interpretation. Statistics provides the tools sharp enough to dig into the old accumulations, extricate and bring to light some of the buried "gold."

It is the purpose of this series to encourage the use of statistics by presenting a few simplified graphical techniques readily usable in Sanitary Engineering. The series will present procedures employing different types of probability papers, graphical tests for statistical significance of series of data and trends, and evaluation of laboratory results.

To illustrate the uses of statistics in Sanitary Engineering consider one problem, that of interpretation of suspended solids determinations at a sewage treatment works. We all know that suspended solids are subject to considerable variation from day to day and from hour to hour. How can we best define and summarize these variations and detect real changes in the load? When is a change significant beyond that expected by chance variation alone? How many individual determinations must we make in order to have a reliable average? When are individual determinations out of line with what is normally expected? How can we make reliable comparisons between influent and effluent?

For intelligent application of the graphical procedure to be developed in subsequent articles, it is first necessary to gain fundamental concepts of the nature of variation of data and the laws of probability.

Definition

Statistics may be defined as the scientific collection and analysis of data, and the projection of estimates therefrom. Statistics is not an end in itself; rather it is an aid to judgment in arriving at valid conclusions, testing theories, measuring phenomena, discovering relationships, or projecting estimates under different conditions. The statistical method is an economical procedure for getting at the facts and determining their significance with confidence. In our enthusiasm over statistics it must be remembered that it is only a tool and is not a substitute for professional knowledge and experienced judgment. Sound judgment, however, cannot be made with confidence without the use of this tool.

Statistical Concepts

The whole concept of statistics is one of *variation*. If there were no variation in data there would be no need for statistical methods. This concept of variation is in conflict with most of the mathematics as it has been taught us. In mathematics we usually start with a preconceived theory which, if followed, automatically must lead to a single exact answer without any deviation. Such inflexible finality is not consistent with the facts of life as we *observe* them. Even with the most precise methods of measurement there is *always variation*. In statistical reasoning we start with observations and with full acceptance of their inevitable variation, which leads not to a single answer but rather a range of answers.

For example, let us suppose we desire to know the weight of an object. A single careful measurement may be 10.1 milligrams, a second measurement made under the same circumstances may be 9.8, and similarly, repeated measurements will show other variations. With these variations in measurements the question arises, Which of these answers is correct? or, What is the exact true weight? The true weight remains unknown and at best can be only estimated. The best estimate is the average of the repeated measurements, in this case, say 10.0. But confidence in any estimate can be had only in defining not a single value but a *range* within which we believe the true weight lies.

From a statistical analysis of the variation of the measurements confidence and range can be related. We are confident of enclosing the true value 68 times in 100 within the range $10.0 \pm .1$ (9.9 to 10.1); or we are confident of enclosing the true value 997 times in 1,000 within the range $10.0 \pm .3$ (9.7 to 10.3). In the second instance our confidence is high; only 3 times out of 1,000 would we be wrong in believing that the true value was within this wider range. But we have gained this added confidence only at the expense of precision; we are less definite as to the exact true weight in the sense of a single value.

In fact, under this new concept we can never determine with finality the exact true weight, because as we narrow the range working toward a single value we lose confidence in enclosing it, with total loss of confidence if an attempt is made at expression as a single value. Thus in expressing measurements we always state a *range;* the mean plus or minus some increment of standard deviation, the increment dependent upon the degree of confidence desired.

The proper evaluation of data in sewage works operation and stream pollution studies cannot be accomplished by simple mathematical averages of a series of analytical results. "Statistical evaluation offers the only means of condensing raw data to concise form, permitting significant interpretation," according to the author. This series of articles on the "Graphical Approach to Statistics," has been prepared especially for *Water & Sewage Works* to show how the usual forbidding methods of statistics can be used by means of graphic solutions. These articles may well revolutionize future work in this field with particular reference to water and sewage analysis for chemical and bacteriological constituents.—The Editors.

The Nature of Variation

If a series of measurements, say weight, made on the same object are sorted in order of magnitude, it will be found that the results vary in a quite systematic manner. Many of the results will cluster near the midvalue and a few will be more or less evenly distributed with greater spread above and below the central majority. Another type of quantitative data consisting of a *sample* from a large population, universe or supply such as a single weight measurement of a number of such objects selected at random, will likewise portray this tendency toward central cluster and symmetrical spread.

If a large number of such measurements are made and plotted on the scale of measurements, each individually represented by a circle, a symmetrical bell-shaped pile develops as shown in Fig. 1. The center of each circle is vertically above the magnitude of its measurement on the (X) scale; the number in each circle is the rank of each measurement arranged in ascending order of magnitude. The measurements cluster so closely about the mean that it is necessary to pile up the circles in order to locate them opposite their position on the (X) scale, thus forming the bell-shaped curve or distribution. This frequency curve of distribution of measurements, referred to as the *normal Probability Curve*, has definite characteristics with respect to the proportion of the measurements found in equal increments of scale as indicated by the numbers across the top of the pile. Those characteristics will be defined more precisely later.

Suffice to observe that the distribution is nicely symmetrical about a *centering value;* with the *deviations* above and below this value spreading out in a very orderly fashion. Other random samples taken from the same universe under the same conditions will reproduce quite similar distributions both as to centering position on the scale and as to deviation or spread. Measurements of different phenomena will develop similar bell-shaped distributions but it will be observed that each has its own centering value and that some vary in the degree of spread or deviation about their central values as illustrated in Fig. 2.

Centering Values

Three centering values are commonly employed: the *Median*, the *Mode* and the *Mean*. The median value is the value exceeded by ½ of the values and of which ½ of the values fall short. It represents the series, if at all, by virtue of its position of dividing the series in half. The mode is the value in the series most frequently repeated and around which other values cluster most densely. It is the high point in the distribution irrespective of the number of terms above and below it. The mean is a simple arithmetic average of the series of data represented by the *sum of the individual measurements divided by the number of observations*. Where the distribution is *normal* (symmetrical), the median, the mode and the mean are identical and coincide. The mean is the most useful centering value and is most frequently employed.

However, an average by itself is a

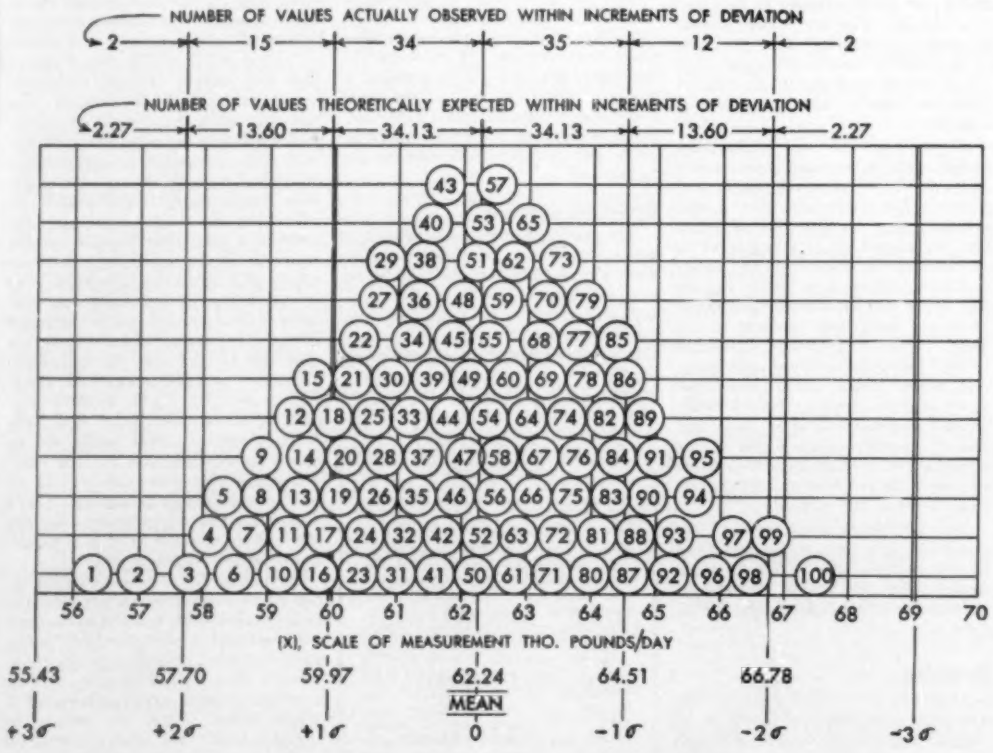


Fig. 1—Demonstration of the Normal Probability Curve

(Distribution of 100 suspended solids determinations; Mean 62.24 thd. pounds per day; Standard deviation 2.27 thd. pounds per day.)

dangerous value. Too frequently series of data are summarized merely by an "average" (the mean) without designating the number of measurements or the nature of variation or spread in the data. For example, consider the following three series of data, X, Y, and Z, which have the same average:

(1) X comprised of 2 values, 1 and 99; average = 50.
(2) Y comprised of 19 values ranging from 10 to 90; average = 50.
(3) Z comprised of 19 values ranging from 47 to 53; average = 50.

While all produce the same average (50), it is not difficult to see that the three averages come from quite different data. In the first instance, two measurements hardly give meaning to an average, particularly when they have a great spread; in the second and third instances, while both have the same number of measurements (19) and the same average (50), the second has a wide spread ranging from 10 to 90, while in the third the data are compact, with a spread ranging from 47 to 53.

Deviation from the Central Value

In addition to the mean and the number of measurements it is necessary to know something of the nature of deviations of measurements about the central value.

The Standard Deviation, σ (Sigma), is the fundamental measure of variation which constitutes the major "building block" in all statistical procedures. It is the root mean square deviation obtained by squaring each individual deviation from the mean, summing, dividing by the number of measurements and extracting the square root of this mean square.

$$\sigma = \sqrt{\frac{\Sigma(X - \bar{X})^2}{n}} \qquad \text{Eq. 1}$$

(There are various other transformations of this equation which are more useful if computations are made by machine; also a simple graphical method of obtaining the standard deviation will be given in the next article.)

The standard deviation is important because, through it, the fundamental characteristics of the normal probability curve are defined and precision can be related to probability or a confidence level.

Probability

As a basis for understanding the graphical applications of statistical procedures, which will be presented in subsequent articles, and the significance of the standard deviation as a measure of variation it will be necessary to gain a concept of *Probability.*

There are two concepts of probability, the one based upon what *can* occur and the other based upon what *has* occurred. If an event can occur or has occurred in (a) ways and can fail or has failed in (b) ways, then the probability of a success is $a/(a+b)$, which is a ratio of the number of ways in which an event can occur or has occurred to the total number of ways of occurrence, each being equally likely to occur. Probability is expressed as a ratio and ranges from *zero* to *unity;* zero designating impossibility; unity designating certainty.

The first concept, based upon what *can* occur, is referred to as *a priori* probability. In tossing a coin there are two ways in which an event can occur, either a head or a tail. The probability of a specified event, head, is therefore ½ or 0.5. There are six ways in which a die can fall. The probability of the event, an ace, is therefore 1/6. These are probabilities before a trial, based purely upon what *can* occur.

The second concept, based upon what *has* occurred, is referred to as *a posteriori* probability, probability after the trial. A coin is tossed 1,000 times and the event, a head, has been observed to occur 506 times. The a posteriori probability of a head, based upon what has occurred, is 506/1,000 or 0.506, as compared with a priori probability based upon what can occur of 0.5.

The a priori or true probability of a universe can exist but it cannot be measured. Repeated random samples drawn from a universe show results varying about the true value, results

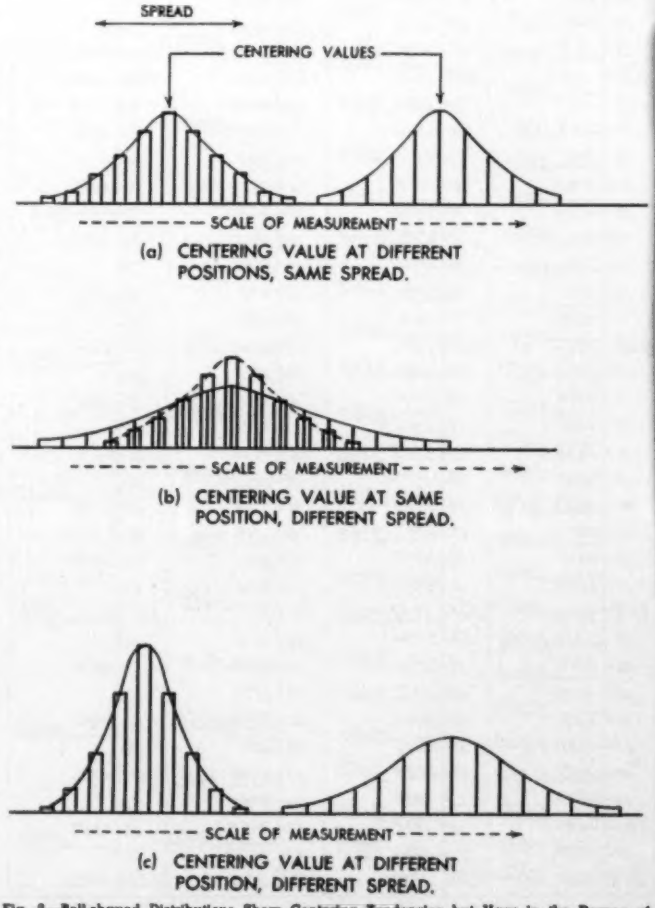

SPREAD
CENTERING VALUES
SCALE OF MEASUREMENT
(a) CENTERING VALUE AT DIFFERENT POSITIONS, SAME SPREAD.
SCALE OF MEASUREMENT
(b) CENTERING VALUE AT SAME POSITION, DIFFERENT SPREAD.
SCALE OF MEASUREMENT
(c) CENTERING VALUE AT DIFFERENT POSITION, DIFFERENT SPREAD.

Fig. 2—Bell-shaped Distributions Show Centering Tendencies but Vary in the Degree of Spread or Deviation

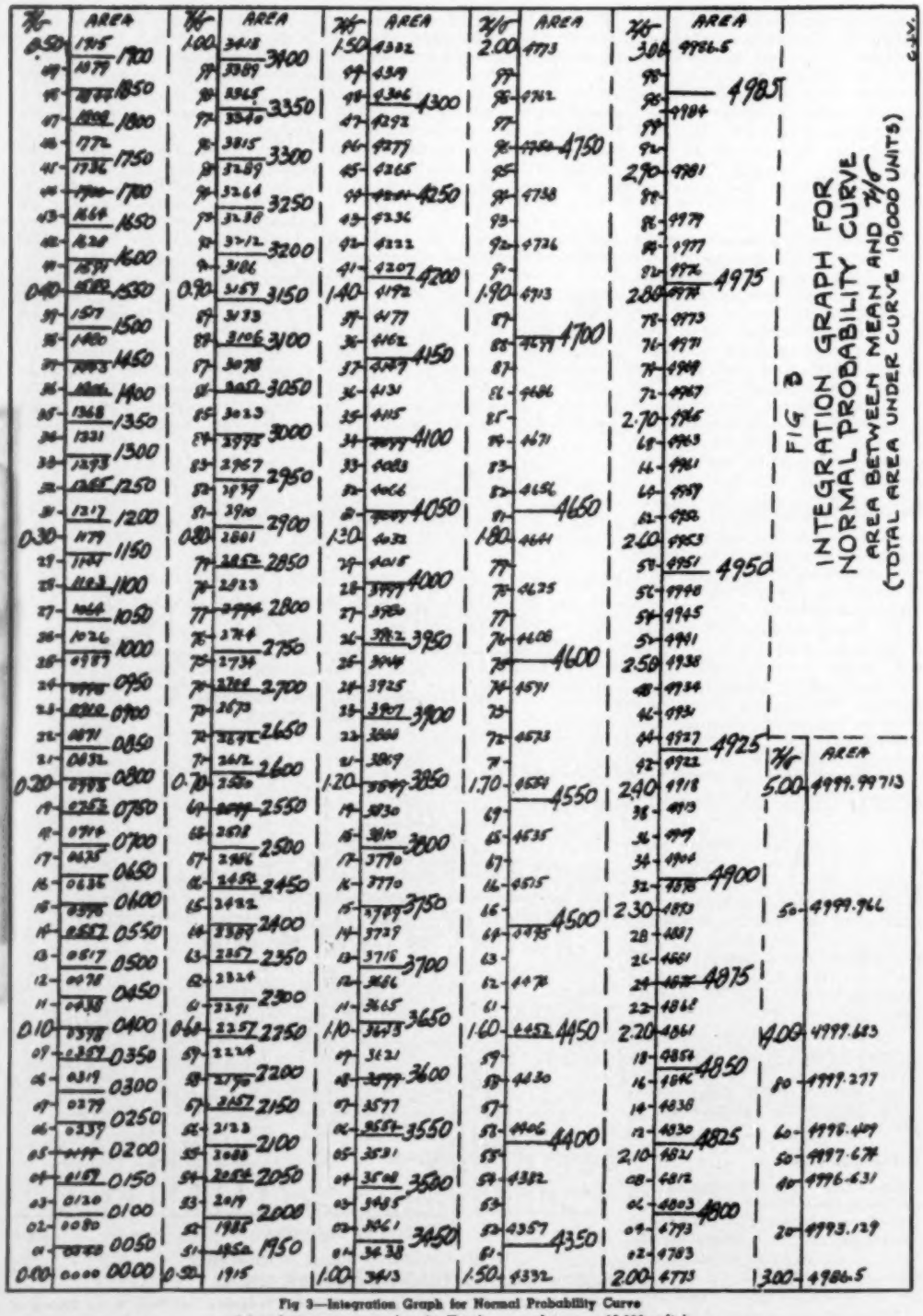


Fig 3—Integration Graph for Normal Probability Curve
(Area between mean and X/σ. Total area under curve 10,000 units)

from the small samples showing greater variation than those from the larger samples. Or as the number of trials approaches infinity the a posteriori probability as determined from the observations approaches the true a priori probability.

Numerical Expressions of Probability

1. The sum of the probabilities of occurence of a complete and mutually exclusive set of events is unity. Impossibility has a probability of exactly zero. The entire range of probabilities extends from impossibility to certainty or numerically from 0 to 1.

2. If the probability of success is p and of failure q then $p + q = 1$; and $1 - p = q$; and $1 - q = p$.

3. The probability of *either* one *or* another of mutually exclusive events occurring is the sum of their individual probabilities. Probability of drawing a spade *or* a heart: $\frac{13}{52} + \frac{13}{52} = 0.5$; of drawing a spare, a heart or a club: $\frac{13}{52} + \frac{13}{52} + \frac{13}{52} = 0.75$.

4. The probability of occurrence of a compound event composed of two or more independent events is the product of the individual probabilities. What is the probability of *two* heads in *two* throws of a coin? (One head on the first throw and one head on the second throw.)

Probability of head on 1st throw = 0.5
Probability of head on 2nd throw = 0.5
Probability of two heads on two consecutive throws $0.5 \times 0.5 = 0.25$

Relation of the Standard Deviation to the Normal Probability Curve

The normal probability curve is a standardized form of distribution where the scale of measurement is in terms of the standard deviation measured from the center of the distribution as the origin. For example, referring to Fig. 1, the (X) scale is weight in thousand pounds per day; and the corresponding (X′) scale is in terms of the standard deviation. The zero of the X′ scale is opposite the center of the distribution, the mean 62.24 thousand pounds per day. Unit distance on the X′ scale is equivalent to a standard deviation, 2.27 thousand pounds per day, measured along the X scale but labeled $+1\sigma$, $+2\sigma$, $+3\sigma$ and -1σ, -2σ, -3σ on the X′ scale. To convert a series of scaled measurements (X) to the standard probability scale X′ it is necessary to know the mean ($\overline{X}$) and the standard deviation (σ). The mean ($\overline{X}$) is the simple arithmetic average and the standard deviation can be computed from the data or, as will be illustrated later, readily obtained graphically.

The significance of the standard deviation (σ) as a measure of variation is apparent from the following analysis of the distribution of the 100 measurements on Fig. 1. Extending two vertical lines at $+1\sigma$ and -1σ on either side of the mean, we count 69 of the total 100 measurements falling within this range, and 31 fall without, 14 above and 17 below. Probability of measurements falling within this range based upon what has occurred is 69/100 or 69 per cent; and of falling without, 31/100 or 31 per cent. Similarly, we count 96 measurements within the range of the mean $\pm 2\sigma$, and 4 measurements without, 2 above and 2 below. The probability of measurements falling within is 96/100 or 96 per cent, and of falling without, 4/100 or 4 per cent.

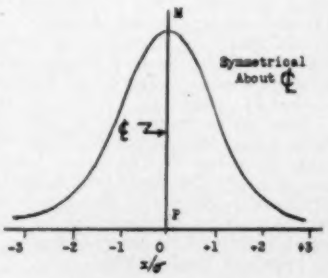
Characteristics of the Normal Probability Curve

These results are based upon a sample of 100 measurements. As the number of measurements are increased the a posteriori distribution approaches the a priori distribution defined by the Normal Probability Curve. The a priori probability of measurements falling within any range are given by the area under the curve between the limits of the range defined in terms of standard deviations from the mean. These areas have been computed for any increment of deviation and are available in tables.

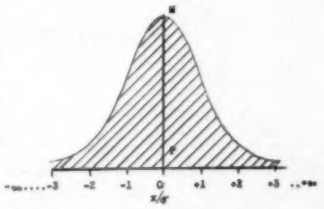
One useful form is the Integration Graph shown in Fig. 3. The areas are given between the central value (the mean) and x/σ (deviation in terms of standard deviation) measured only in one direction from the mean.

The Probability Curve has the following six characteristics:

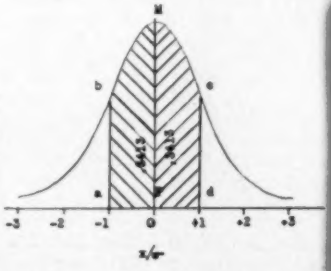
1. All events are distributed symmetrically about the "mean" or the "most probable" M.P. value.



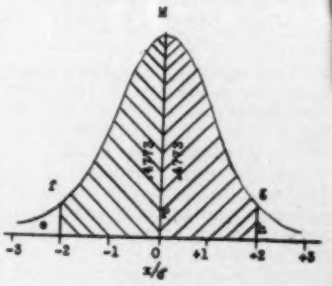
2. The Probability Integral for the complete distribution of events is the area between $\pm \infty$ which is unity. Pb of all events = 1.0.



3. The Probability Integral for all events between the limits of $\pm 1\sigma$ ($Dev/\sigma = 1$) from the M.P. value is the area (abcd) which from the Integration Graph is $2 \times 0.3413 = 0.6826$. Thus 68.26% of all events lie within a range of $\pm 1\sigma$ from the M.P. value and 31.74% of the events lie without this range.

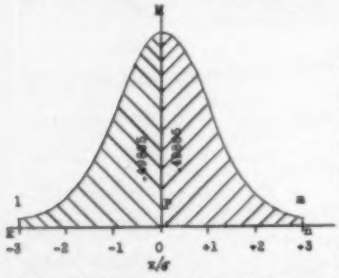


4. The Probability Integral for all events between the limits of $\pm 2\sigma$ ($Dev/\sigma = 2$) from the M.P. value is the area (efgh) which from the integration graph is $2 \times 0.4773 = 0.9546$. 95.46% of all events lie within a range of $\pm 2\sigma$ from the M.P. and 4.54% of events lie without this range.

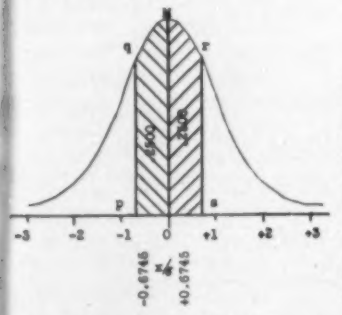


5. The Probability Integral for all events between the limits of $\pm 3\sigma$ ($Dev/\sigma = 3$) from the M.P. is the area (klmn) which from the integration graph is $2 \times 0.49865 = 0.9973$. 99.73% of all events lie within the

range of $\pm 3\sigma$ from the M.P. and 0.27% of events lie without this range.



6. The Probability Integral for all events between the limits of $\pm 0.6745^{\sigma}$ (Dev/$^{\sigma}$ = .6745) from the M.P. is the area (pqrs) which from the integration graph is $2 \times 0.2500 = 0.5000$. 50% of all events lie within the range of $\pm$ 0.6745$^{\sigma}$ from the M.P. and 50% of events lie without this range. This is sometimes referred to as the range of Probable Error (P.E.)



Uses of Probability Integration Graph

Let us suppose we wish to define the quality of effluent of a sedimentation tank in terms of suspended solids. The mean of 30 determination is 102.0 ppm, but values vary about the mean with a standard deviation from the mean ($^{\sigma}$) of 5.5 ppm. From what has been said heretofore, we must define quality of the effluent by a range and we wish to know the confidence of enclosing the quality in that range.

For example, suppose we make the statement that the quality of effluent is within the range of 102.0 $\pm$ 10 ppm.; What is our confidence that this range encloses the quality? or, What risk do we take in having the quality measurement fall outside this range? This we determine from the integration graph:

Deviation from the mean = $\times$ = 10 ppm;

Deviation from the mean in terms of standard deviation, $x/\sigma = \frac{10}{5.5} = 1.82$.

Opposite x/σ of 1.82 on the Integration Graph, Fig. 3, read area 46.56 per cent or probability for the range, Mean $\pm$ 1.82σ, is 2 $\times$ 46.56 per cent or 93.12 per cent.

We are about 93 per cent confident of enclosing the quality of the effluent within the range of 102.0 $\pm$ 10 ppm. In accepting this range as defining the quality we run the risk of being wrong about 7 times in 100, as 7 times in 100, deviations greater than $\pm$ 10 ppm are expected.

Again suppose we do not wish to be wrong in our range of quality more often than once in 100, then in 99 times in 100 we must be right. This requires an area in one direction from the mean of 99/2 or 49.5 per cent. Opposite area of 49.5 per cent on the Integration graph, Fig. 3, read $\times/^{\sigma}$ of 2.567. The range then is defined by the mean $\pm$ 2.567$^{\sigma}$ or 102.0 $\pm$ 2.567 $\times$ 5.5, 102.0 $\pm$ 14.1 ppm. In other words, in saying that the effluent quality is 102.0 $\pm$ 14.1 we are 99 per cent confident of being right and only once in 100 would we expect to be wrong by having quality fall outside of this range.

If we are willing to accept even chance of being right or wrong, the range can be narrowed. This requires an area in one direction from the mean of 50/2 or 25 per cent. Opposite area of 25 per cent on the Integration Graph, Fig. 3, read $\times/^{\sigma}$ of 0.6745. The range then is the mean $\pm$ .6745$^{\sigma}$ or 102.0 $\pm$ .6745 $\times$ 5.5 ppm = 102.0 $\pm$ 3.7. Now we have a narrower range but we do not have great confidence in it because half of the time quality of the effluent is expected to fall outside the limits of this narrower range.

In the next article we shall transform the bell-shaped probability curve and its integration graph into a straight-line on probability paper so that answers to questions such as these as well as others can be directly read at a glance.

Milwaukee to Start Water Fluoridation First of Year

Use of Silicofluoride Will Save $78,000 Yearly in Chemical Cost

Fluoridation of Milwaukee's water supply beginning Jan. 1, 1951, has been authorized in a resolution by the common council's joint public utilities and finance committee.

The committee rejected July 1, 1950, as a starting date for the fluorination process on the grounds that money had not been set up in this year's budget.

Dr. E. R. Krumbiegel, city health commissioner, advised the committee that fluoridation would cost about $20,000 a year for the sodium silicofluoride to be used. That is only one-fifth of the cost estimated when the council considered an earlier fluoridation ordinance.

Originally it had been intended to use sodium fluoride, which would have cost about $98,000 a year.

Equipment to feed the chemical into the water was estimated to cost about $15,000.

Friel Named to ASCE Board

Francis S. Friel, president of the consulting engineering firm of Albright & Friel, Inc., Philadelphia, Penna., has been appointed a member of the Board of Direction of the American Society of Civil Engineers to fill the vacancy created by the death of Joel D. Justin.

Long active in the Society, Mr. Friel is past president of the Federation of Sewage Works Assns. and is a member of the Board of Trustees of Drexel Institute of Technology of which he is an alumnus and from which he received the honorary degree of Doctor of Engineering.

News Item!

First "Sweet-Water" Well in Bermuda Located With Hazel Twig.

A water-diviner with a hazel twig, cut from a nearby bush, has located the first sweet-water well ever dug in Bermuda. Water was struck at the 80 ft. level.

An "U.P." release from Hamilton, Bermuda, tells of a water-diviner brought to the island from the United States by novelist Kenneth Roberts, having located the spot for the well drillers.

The water was tasted by Roberts and his drillers who pronounced it "clean, soft and fresh." A laboratory analysis later confirmed the taste test and certified the well as a partial solution to Bermuda's water supply problem. However, no one has attempted to predict how long after regular pumping starts the water from Robert's well will continue "sweet."

SEWAGE TREATMENT PLANT EQUIPMENT

Racks, Comminutors, Grinders, Triturators

The First of a Series of Articles

by
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SOME years ago Dr. Karl Imhoff made a rather extensive tour of United States and Canada inspecting sewage treatment plants. Near the end of this trip he observed to the late Mr. Harrison P. Eddy, that "in America it is fashionable to be mechanical." The trend, as observed by Dr. Imhoff, has continued and developed so that today it is not only fashionable, but practically necessary "to be mechanical" in order to take advantage of advances and developments in sewage treatment methods and processes.

The Author

Mechanization of Sewage Treatment

The mechanization of sewage treatment has not been, and is not free of problems which trouble designers, manufacturers, and operators. Initial installations of new processes and equipment are usually accompanied by difficulties necessitating changes, adjustments, and further developments. Even in the case of equipment which has been used for many years, it is desirable occasionally to evaluate experiences and to consider what lessons have been learned and what improvements can be made. It is recognized that the individual experiences may not be general. The characteristics of sewage and of the materials removed therefrom, vary so widely from time to time and from place to place that individual experience with any particular piece of equipment may range from highly satisfactory to unworkable. There is an old saying that "what is one man's food is another man's poison," and another that "the proof of the pudding is in the eating."

However, from the extensive experience with many treatment plants, some general conclusions can be derived which should be helpful to sanitary engineers in their search for the best equipment for any particular service.

The designing engineer's problem is to specify and procure equipment that will perform the desired services in a satisfactory manner for a reasonable life and involve a minimum of maintenance and operating expense. The manufacturers, without doubt, have similar aims, but they are in general in a highly competitive field, and unless the plans and specifications are clear and specific, the client may not always obtain the best equipment for the particular service. Much equipment in the sewage works field is subjected to abrasive and corrosive conditions. Equipment must be sturdy and careful attention given to choice of materials or to painting and protective coatings. Ready replacement of parts subjected to wear should be provided for. Equipment which does not satisfactorily perform the service for which it was provided causes headaches to the operators and reflects unfavorably upon the designing engineers and the manufacturers.

Sewage plant mechanization places certain responsibilities on the authority served. The necessary personnel and funds for maintenance, operation, renewals and repairs must be provided. The personnel must be capable and willing to make the equipment function in accordance with its purpose. A great deal of expensive equipment at sewage treatment plants may be seen lying idle, serving no useful purpose and deteriorating from lack of the necessary funds or the will or the know-how to make it work. Some of this idle equipment was possibly not suitable in the first place, but much of it could be operating successfully with proper care.

RACKS

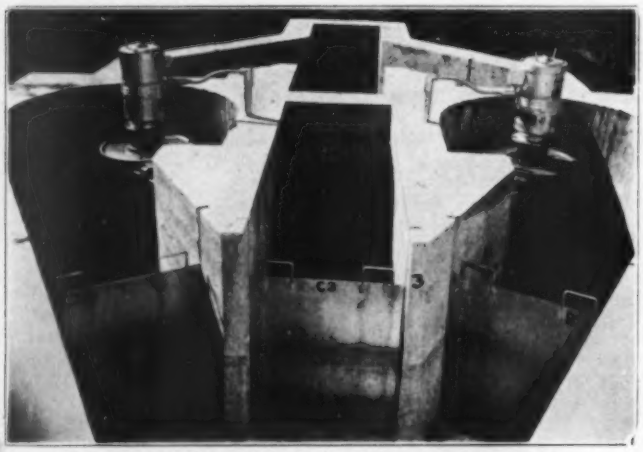
The operation of mechanically cleaned racks has frequently been accompanied by excessive wear on moving parts, stalling of the rakes, failure of float-operating controls to function, excessive corrosion of rakes and bars and other difficulties with resultant excessive repair and maintenance costs. Improvements and refinements in design make it possible to eliminate some of these troubles.

The difficulties encountered in the operation of large mechanically cleaned racks within the Chicago Sanitary District, have been given considerable study and analysis. The fundamental principle of design which greatly reduces the cost of maintenance and repairs as reported by L. M. Johnson[1] may be summarized as follows:

1. All parts should be designed to carry any loads required of them.
2. Motors should be selected within the maximum safe stresses of all parts.
3. Removable mild steel wearing strips should be provided on chain guides.
4. The rack mechanism should be pivoted at the floor line so that it can be lifted out of the flow in the event of a jammed rake.
5. The chains should be of heat-treated malleable iron.
6. The sprocket teeth should be chilled to produce extremely hard wearing surfaces.
7. Wide wearing shoes should be provided on the chain side bars.
8. The rake teeth should be of high bending strength and readily replaceable.
9. The rakes should be operated intermittently by time switches.

The city of New York accepted a design of mechanical rack-cleaning equipment for the Manhattan grit chambers in which the teeth entered the screen bars against the flow at the bottom. Thence the rake moves in an upward direction with the teeth protruding between the bars out on the face of the rack carrying screenings along the bars and over the top. The rakings fall off as the rakes disengage

(1) Municipal Sanitation, August 1938, page 391.



Bristol, Conn.—Bypass Rack and Chicago Pump Co. Comminutors

the screen bars. The results of operation of this installation at the Manhattan grit chambers were so satisfactory that the city of New York has, we believe, settled upon this type of rack for subsequent installations.

After a thorough investigation of the operation of the racks at the Manhattan grit chamber, Mr. Karl R. Kennison, Chief Engineer, Construction Division, Boston Metropolitan District Commission, adopted this type of rack with some modifications for the racks at the Nut Island plant in the Boston South Metropolitan Sewerage District. This type of rack has also been adopted for installation ahead of the main sewage pumps at the Toronto Ashbridges Bay sewage treatment plant.

For a while, it appeared that comminutors possibly would displace mechanically cleaned racks generally as the first step in treatment at sewage treatment plants for all except very small and very large plants. However, it has developed that comminutors may advantageously be preceded by grit chambers in order to reduce the cost of replacement of worn parts. Grit chambers are now almost universally required at sewage treatment plants regardless of whether or not the sewerage system is on the separate or the combined plan. In most instances, such grit chambers, particularly where equipped with mechanical grit-removal mechanisms should be preceded by coarse or medium racks. Thus it would appear that mechanically cleaned racks will still be required for many sizeable sewage treatment plants in the future.

Operation Control

Experience has indicated that the maintenance work required on racks is substantially in proportion to the hours of operation. Consequently controls have been developed to assure that the racks will be operated intermittently as needed.

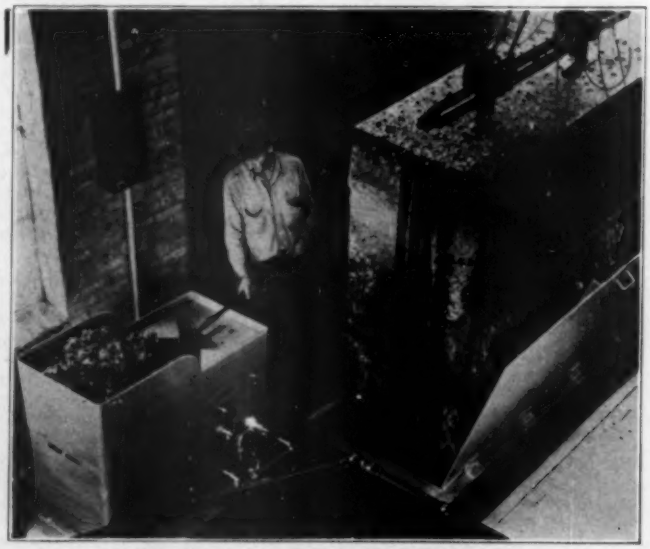
Common methods of control include time clocks and floats operating on either high-water level in part of the rack or the differential water level in front of and following the rack.

The clocks can be set to operate the racks intermittently. To eliminate possible overload on the rack between periods of operation, it is customary to set the operating time interval so as to take care of the maximum rate of accumulation of materials on the rack. Obviously, for much of the time, the rack operates more frequently than is required, resulting in unnecessary wear on the mechanism and on the controls. The clock controls involve less installation cost than float or air controls and are not subjected to the difficulties encountered with float controls.

Some authorities require that all mechanical rack operating units, normally operated by timing devices, be provided with auxiliary float controls which will set the raking mechanism in operation at predetermined high-water marks independently of the timed control.

The use of float controls has been troublesome at some installations because of solids accumulating on the floats and on suspension cords and because of their corrosion in the rack channels. The condition as regards the accumulation of materials on floats has been corrected in part at least, by providing float wells adjacent to the rack channels and connected thereto. A small quantity of flushing water creating a flow from the float wells into the rack channels can be provided to keep the float wells reasonably fresh and free of sewage solids. Corrosion can be overcome for the most part by careful selection of materials of construction.

To eliminate the difficulties encountered with float controls, a system of controls which rely on differential air pressure in pipes, immersed in the sewage in front of and behind the rack has been developed.



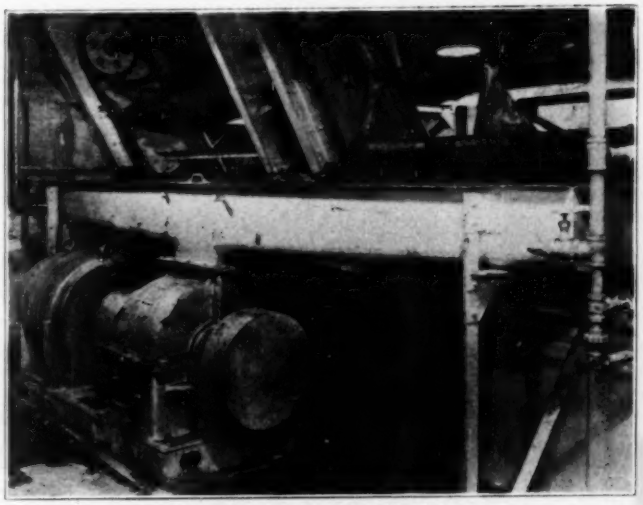
Elgin, Ill.—Cage Rack and Chain Belt Co. Triturator
(Screenings Removed by hand for grinding)

This system is reported to give very satisfactory results. A small amount of air is necessary to activate the controls.

Rakings

The materials removed by racks are offensive to sight and smell. It is desirable to dispose of them promptly with a minimum of handling. Much of the material removed by racks can be disposed of with the other sewage solids after grinding or comminution. Pieces of metal and sizeable chunks of wood should be removed from the rakings and disposed of separately. The common methods of preparing the solids returnable to the sewage flow, are by comminutors, grinders, and triturators. At the Los Angeles Hyperion plant, the rakings removed by the racks ahead of the Dorr detritors will be treated by an installation of Chicago comminutors. At the Toronto Ashbridges Bay plant, each of 6 racks will be equipped with a Jeffrey grinder. The rakings will be discharged onto a sorting table and manually fed to the grinders after materials not suitable for grinding or return to sewage flow have been removed.

At Baltimore, there are a number of installations at which the rakings at each rack discharge to a short belt conveyor. These rakings are thence carried to a separate grinder for each rack and are comminuted. Keefer reports that these installations work automatically without the necessity for manual removal of metallic and bulky materials. The evidence at several other plants is that it is not safe to rely upon automatic operation for feeding rakings to the grinders.



Screenings Grinder—Jeffrey Mfg. Co.

COMMINUTORS

For purposes of discussion the word comminutor will be used to denote mechanisms which intercept and cut up coarse sewage solids while still immersed in the sewage flow. Until recently the Chicago Pump Co. comminutors have had competition in this field primarily from a combination of mechanically cleaned rack and grinder or triturator. The Worthington comminutor has been introduced recently and other machines for cutting up solids in the sewage flow have been, or are being developed.

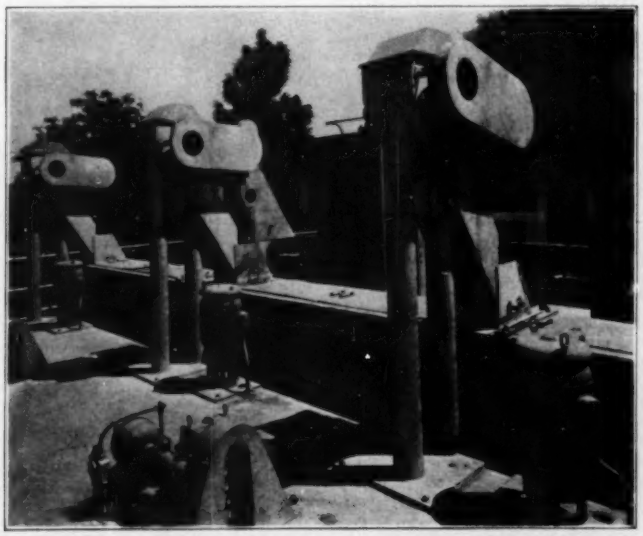
While the teeth, comb, and drum of the Chicago comminutor have been made of tough, wear-resisting metal, experience has shown that the wear is considerable, particularly on combined systems, unless the comminutors are preceded by grit channels. The Chicago Pump Co. has made recommendations for location of comminutor in respect to grit chambers as follows:

"Where grit chambers are required to remove heavy grit from combined sewage or gravel from street-wash, it is preferable to locate the comminutors downstream from grit chambers.

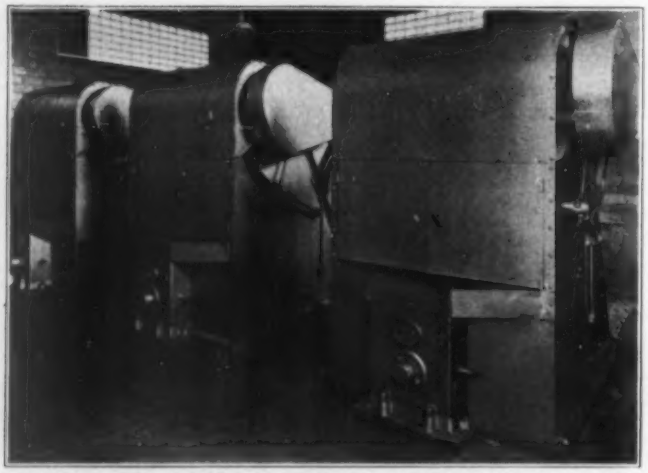
"Where it is not feasible to locate comminutors downstream from grit chambers due to structural difficulties, or to the possibility of clogging mechanical grit-removal mechanisms by uncut rags, special precautions should be taken to make the comminutor basin as accessible as possible for periodic removal of grit by the operator, to prevent undue accumulations."

Where grit chambers are required but conditions do not make it advisable to install mechanical grit-removal equipment, the comminutors usually can be conveniently located following the grit channels. Where mechanical grit-removal equipment is provided and comminutors are located ahead of the grit channels, then not only must the special precautions noted by the Chicago Pump Co. be followed but it should be recognized by the designer, operator, and owner that the necessary labor and expense must be provided to maintain reasonably sharp teeth and to replace worn parts as required.

At the Nut Island plant, Boston, it was deemed advisable to install



Decatur, Ill.—Screenings and Grit Separators Mechanisms by Walker Process Equipment Co.



Denver, Colo.—Automatically Cleaned Bar Screens and Chain Belt Screenings Triturator

mechanically cleaned coarse bar racks ahead of the mechanically cleaned grit channels and to provide comminutors to handle the normal dry-weather flow at the effluent end of the grit channels. Supplementary mechanically cleaned fine screens were provided at the effluent end of the grit channels to treat storm flows in excess of normal maximum dry-weather rates. The screenings removed by both the coarse and fine racks will be returned to the sewage flow ahead of the comminutors. The comminutors were supplied by the Chicago Pump Co. and the rack equipment by the Jeffrey Manufacturing Co.

GRINDERS AND TRITURATORS

Machines for cutting up sewage solids are removed by racks and screens, out of the sewage flow, are available in two main types, the grinder as manufactured by Jeffrey and by Gruendler and the triturator as manufactured by the Chain Belt Company. The grinder is designed to grind the screenings between a high-speed rotor equipped with swing hammers, and a serrated shredder plate. The swing hammers are commonly made of high-carbon steel hardened and tempered, made easily removable and capable of being shifted end to end and side to side so as to give four wearing edges. The shredder bar assembly is also usually made of high-carbon steel, hardened and tempered, and with easily replaceable bars.

The triturator at one time consisted essentially of a toothed rotor revolving at high speed between two grates, the cutting teeth intermeshing the grate bars. As presently described, the toothed rotor operates against a perforated screen for positive extrusion of the rakings through the screen holes and simultaneous shear cutting by the teeth against the screen.

At Buffalo, N.Y., the screenings from the fine racks were passed through triturators for the first six years of operation at the Birds Island plant. For the past four years, however, the screenings have been disposed of by burial after the operators reached the conclusion that handling, transporting and burial presented less of a problem than grinding. At this plant, it was found that the screenings contained so much hard material, such as bits of stone and pieces of metal and wood, that the effective life of the teeth was very short. New or resharpened teeth became dull in a very few hours of operation and then did not properly shred the material passed through them. This gave a great deal of trouble further along because of the condition in which the rags were left.

Both grinders and trituratorshave been in successful operation for at least ten years in moderate-sized sewage treatment plants with which we have been associated as engineers.

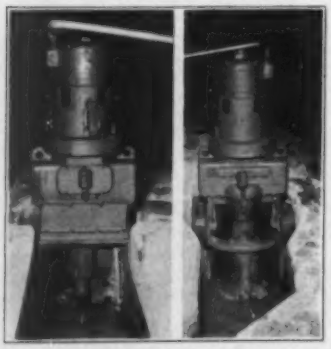
Balls of material have been known to accumulate on the grinder shredder plate which cause trouble later on in the plant as they finally drop off. It is believed advisable, when feasible, to return the discharge from grinders and trituratorsto the sewage ahead of the racks.

Other Operating Information

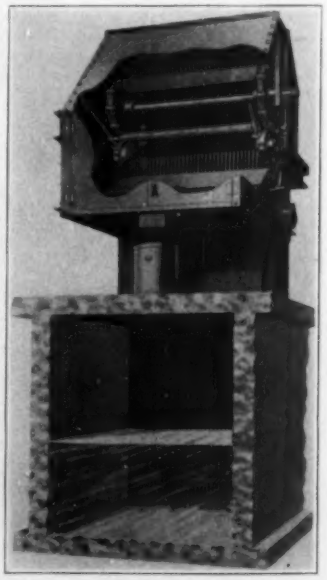
As typical examples of operating installations the following paragraphs set forth information on three plants.

A mechanically cleaned bar rack and grinder as supplied by the Jeffrey Mfg. Co. was installed at the North Adams, Mass., sewage treatment plant during 1936 and has completed 13 years of operation. The maintenance work on the individual parts as reported by Paul Fleming, Plant Supt., has been very small. The rake jams occasionally if the chains become uneven, but this has not been considered serious by the operators. Automatic operation of the grinders is not employed as it has been learned from experience that large masses of rakings will clog the grinder necessitating opening it up and cleaning it out. New rotor weights have been placed on the hammers three times in 13 years. This involves only a moderate expense.

A mechanically cleaned bar rack and triturator as supplied by the Chain Belt Co. and installed at the Tona-



Essex Falls, N.J.—Worthington's Comminutor



Thru-Clean Bar Screen by Link-Belt Co.

wanda, N.Y., sewage treatment plant was placed in operation in 1940. The operating experience has been reported to the author by James J. Kampas, Chief Operator, and Benjamin Hinkey, City Engr. The rake is operated either by time clock or manual control. Large objects have at times jammed the rakes at the bottom of the rack necessitating dewatering the rack channel for their removal. It has been found necessary to replace the rakes, bars, lower sprockets, and scraper arms because of wear and tear. The triturator teeth are periodically sharpened and need to be replaced on the average after two to three years of service.

Inquiry has also been made as to the operation of the rack equipment at the Bloomington and Normal Sanitary District. In the January 1940 issue of Water Works and Sewerage, the satisfactory operation of the Chain Belt mechanically cleaned bar rack and triturator was described by Orie J. Hendryx, then Supt. of the Bloomington and Normal Sanitary District. Mr. George L. Hall, the present superintendent of this plant reports to the author that the original equipment is still in use except that the chain was replaced in 1948. Equipment to replace the lower boot section including sprockets and pins is at hand to make this replacement when it becomes necessary. Mr. Hall reports that the operation of the equipment during the past eight years has been satisfactory.

Engineering Profession Invites Suggestions on National Water Policy

Representing the five National engineering societies, the Water Policy Panel of the Engineers' Joint Council has undertaken the highly important and timely task of developing a statement on the water resources of the Nation, with particular reference to the use and abuse of water supply sources.

The immediate objective of the Committee is the production of a statement of professional engineering opinion pertaining to policy and practice in conservation, utilization and protection of water resources, with especial emphasis on immediate and long range development of public water supply for domestic, industrial, agricultural and recreational uses.

The Water Policy Panel of E.J.C. has been asked by the President's "Temporary Water Resources Commission" to speed the development of its report for consideration by and guidance of this important new Federal agency. In consequence the Task Committees, named jointly by the E.J.C. Water Panel and the Panel's special Coordinating Committee, are working under pressure to develop recommendations on a water resources policy at the National, State and Municipal levels within a 60 day period, the deadline being set as June 1, 1950.

The Water Policy Panel's special Coordinating Committee to which the eight Task Committees will report is headed by Dr. Abel Wolman of Johns Hopkins University as Chairman. W. W. Horner of St. Louis, past-president of A.S.C.E., is general chairman of the Water Policy Panel.

The eight Task Committees, appointed jointly by Chairman Horner and Wolman, and their respective Chairmen are—

Comm. No. 1—"Domestic and Industrial Water Supply and Pollution" *(Chairman, L. R. Howson, Cons. Engr., Chicago).*

Comm. No. 2—"Flood Control and Water Flow Retardation" *(Chairman, J. A. Short, Mo. Dept. of Resources and Development, Jefferson City, Mo.).*

Comm. No. 3—"Navigation and Water Transportation" *(Chairman, Col. Cary H. Brown, Eastman Kodak Co., Rochester, N.Y.).*

Comm. No. 4 — "Irrigation" *(Chairman, S. T. Harding, Univ. of California, Berkeley, Calif.).*

Comm. No. 5 — "Hydro-electric Power" *(Chairman, Col. F. W. Sheidenhelm, Cons. Engr., New York).*

Comm. No. 6—"Recreation, Fish and Wild Life Aspect of Water Resources" *(Chairman, M. P. O'Brien, Univ. of Calif., Berkeley, Calif.).*

Comm. No. 7—"Basic Water Resources Information" *(Chairman, G. R. Williams, Cons. Engr., New York).*

Comm. No. 8—"Land Drainage" *(Chairman, Edmund Friedman, Cons. Engr., Miami, Fla.).*

At the organization and planning meeting of Task Committee Chairmen, with members of the E.J.C. Water Panel and Coordinating Committee, it was the expressed desire of the Committee Chairman and the sense of the group that expressions of opinion and constructive suggestions regarding a National Water Policy be invited from the engineering profession at large, water supply officials (domestic and industrial) and stream control authorities.

It is thus the expressed wish of the Task Committee Chairmen that on a matter of such importance to the Nation at this juncture that this desire for opinions and policy statements be given wide distribution.

Time being extremely short in which to develop the composite Emergency Report for use by the President's Water Resources Commission, constructive suggestions and recommendations to Task Committee Chairmen must be contributed promptly.

It Has Come to This!

The water supply situation in New York City has caused the Department of Water Supply to issue advance notices that there will be no sprinkling of lawns or watering of gardens permitted this summer. No air conditioning equipment will be permitted to operate unless or until water conserving evaporative condensers, or the equivalent, are installed.

Looking ahead to the effects of water supply restriction during next summer, and probably for some summers to come, many establishments are putting down drilled wells all over the city and developing independent emergency supplies.

One of the most publicized of these emergency wells is that which is being drilled out in the right field corner of Ebbett's Field, home grounds of the Brooklyn Dodgers baseball club. The 135 ft. well is expected to yield 60 gals. per minute, which will be sufficient water to keep the grass green, wash down the seats, and supply most of the other water requirements of the field except drinking water. Someone, however, has pointed out that the contractor putting in the well and supply system is an ardent "Yankee" fan, so it could be that something might happen to this venture.

The investment in the well and other parts of the system will go to $10,000 and possibly higher—proving that WATER can be worth what you have to pay to get it when there is no other way.

In connection with the flat (fixture and outlet) rate system employed by the N. Y. City Dep't. of Water Supply for its "Water Tax" charges a question is posed. Will the City (can it legally) charge us for the three outside hose connection on which we are "water taxed," as long as the consumer is forbidden to use such outlets?

A SENSITIVE TURBIDIMETER

D. H. MATHESON
Chemist & Bacteriologist
FILTRATION PLANT
HAMILTON, ONTARIO

PRECISE measurements of the turbidity of water and other liquids in the very low range is a difficult matter. Visual methods, with or without instrumental aids, are not entirely satisfactory because of the factor of personal judgment involved. Photoelectric methods offer means of avoiding this factor, but are technically difficult of application when extremely low turbidities are involved. If in this method, percent absorption due to the turbidity is to be measured, it is necessary to measure the very small difference between two fairly large photocurrents, each or both of which may be subject to slight erratic variations due to environmental factors not under strict control. If nephelometric methods are employed, it is necessary to measure the photocurrent generated by the extremely small amount of light scattered by the particles in water of low turbidity. This procedure is not feasible if the convenient self-generating type of photocells are to be employed.

Since precise and highly reproducible measurements of low turbidity are much to be desired in water purification plants in routine and experimental work, an effort has been made to develop a suitable photoelectric turbidimeter applicable in the range of 0 to 10 ppm. The method adopted as being most practicable was that of measuring light absorption due to the turbidity, and in order to obtain percent absorptions high enough to be in the measurable range a long absorption cell is required. Under these conditions, extreme rigidity of construction is necessary to obtain the required stability.

The Instrument Developed

The instrument, shown in general view in Figure 1a and schematically

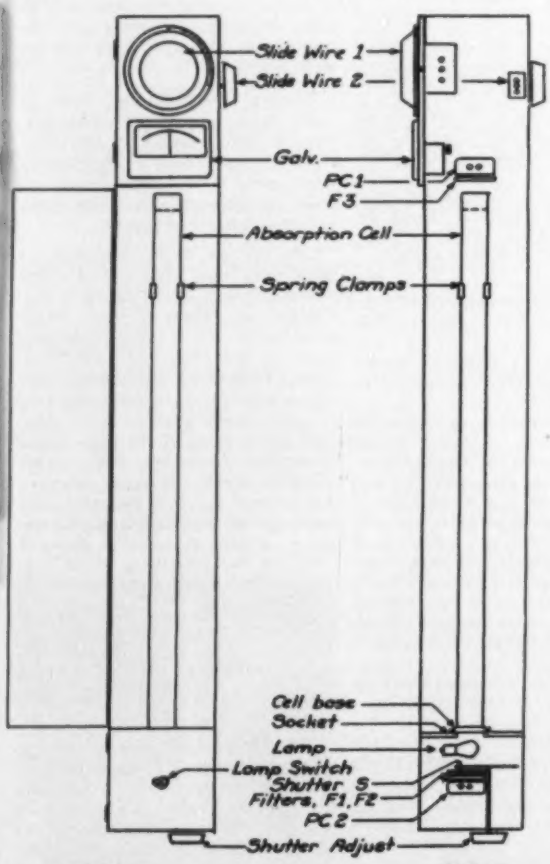


FIG. 1a

FIG 1b

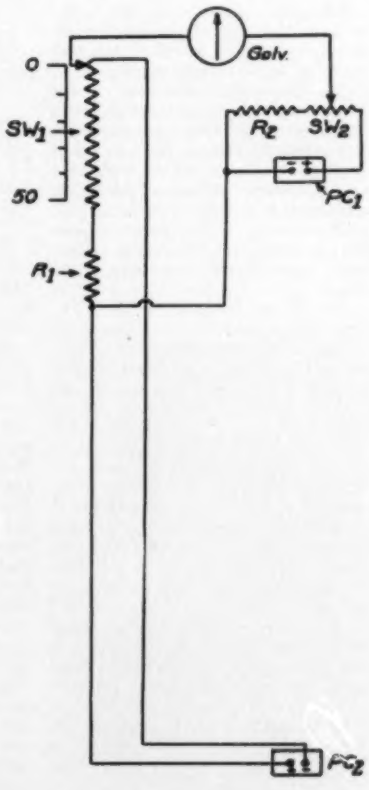
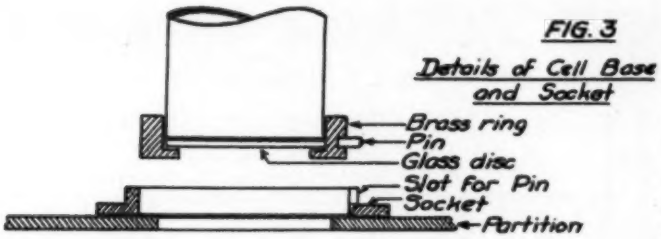


FIG. 2

Figs. 1a & 1b—Schematic General View of Photoelectric Turbidimeter

Fig. 2—Wiring Diagram—A Well Known Circuit



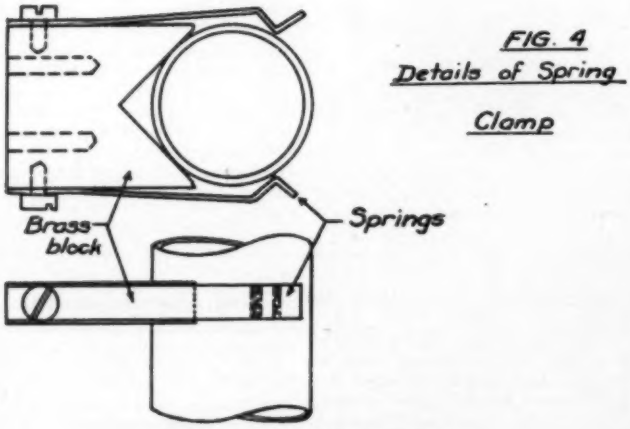


Fig. 3—Details of Cell Base and Socket

Fig. 4—Details of Cell Tube Spring Clamp

in Figure 1b, is mounted permanently on a wall with the graduated dial at eye-level. The case is divided into three compartments, each with a hinged door. In the bottom compartment a 15-cp clear 6v. lamp is rigidly mounted with the filament on the axis of the instrument and placed as close as convenient to the bottom of the absorption cell. This allows a large solid angle of radiation to be received by the bottom of the cell, and almost all of this incident light is transmitted to the top of the cell because of total reflections from the inner surface of the tube. The lamp is operated by a storage battery maintained at medium charge by a trickle charger. Since light is required for only a short period for each measurement the demand on the battery is not large. The highly constant voltage supplied by a battery is essential when such small increments of absorption are to be measured. Below the lamp a comparison photocell PC_2, is mounted, over which are placed the color filters F_1 and F_2, and the adjustable shutter, S, which is used in the initial balancing.

The removable absorption cell in the middle compartment is a glass tube 100 cm. long by 3.0 cm. diameter, closed on the bottom by a glass disc held in a brass ring, both of which are cemented to the tube to make a water-tight joint. A line is etched around the tube 1.5 cm. from the top to serve as a convenient reference mark in filling. The tube requires a sample of 550 ml. partition between this compartment and the lower one is a brass plate with a central round hole, around which is a brass socket which receives with a close fit the brass ring on the bottom of the absorption tube. A pin in the cell bottom engages a slot in the socket, so that the cell can be returned to the instrument always in exactly the same position. Details of the construction of these items are shown in Figure 3. The upper end of the absorption cell is held in a spring clamp, the details of which are shown in Figure 4.

The upper compartment contains the measuring photocell PC_1 and its associated filter F_3. On the door of this compartment are mounted the galvanometer and slide-wire SW_1 with its graduated dial. The second slide-wire SW_2 is mounted on the side of the case and is adjusted by a small knob on the outside.

How the Turbidimeter Operates

The wiring diagram, a well known photoelectric circuit, is shown in Figure 2 where the parts are placed in approximately the same position they occupy in the instrument. The photocells (Weston, photronic 594RR) were selected to match as closely as possible. The measuring cell PC_1 is shunted by a resistance circuit composed of a fixed resistor R_2 of 1900 ohms and a slidewire SW_2 of 100 ohms in series. This control is used as a fine adjustment in balancing. The comparison photocell PC_2 is shunted by a 1000 ohm fixed resister R_1 and the precision slide-wire SW_1 of 1000 ohms. The photocells are therefore shunted by equal resistances, and if they receive light fluxes of equal intensity will produce equal photocurrents and therefore equal voltage drops across their respective resistances. This condition is shown by zero galvanometer deflection when it is connected as shown. When PC_1 receives less light flux due to the absorption of the sample, the voltage drop across its resistors is less, and the galvanometer balance is obtained with the moving contact of SW_1 at a lower point of the slide-wire. The dial on this slide-wire measures the light absorption of the sample directly, and covers the range from 0% to 50%. The galvanometer used is a relatively inexpensive micro-ammeter, 25 microampere movement with center zero.

In order to render the instrument as insensitive towards color as possible, color filters F_1 and F_2 are inserted in front of the photocells as shown. Corning No. 3482 filters (unpolished 2 inch squares) were chosen for this instrument, as they pass approximately the same wavelength band as the color of natural waters. In addition a Corning No. 3966 filter (heat-absorbing) was placed over the lower photocell to minimized heating of the sensitive surface due to its close proximity to the lamp.

To balance the instrument, the absorption cell is filled with distilled water to the mark and placed in the instrument. It is imperative that the outer surface of the tube be kept free of contamination by finger prints, lint, etc., and that sufficient time be allowed for air bubbles to escape. Slide-wire 1 is then set at zero on the dial, and slide-wire 2 at about its mid-point. The lamp is then turned on and the

galvanometer brought to zero by adjusting the shutter over PC_2. Some adjustment in the shape of this shutter may be required to enable this balance to be obtained. When this is accomplished, minor adjustments from day to day are made by adjusting slide-wire 2.

Calibration Procedure

The instrument is calibrated by the use of a standard turbidity of 100 ppm. prepared according to Standard Methods of Water and Sewage Analysis. Dilutions of this standard within the range of the instrument are prepared using distilled water, and the absorption of each is determined by balancing the galvanometer by using slide-wire 1. A curve connecting percent absorption with turbidity may be constructed from which unknown samples are read. More conveniently for routine work a table showing the turbidity corresponding to each of the dial divisions may be prepared.

In any prolonged series of readings a small drift of the zero will be encountered. Occasionally a tube of distilled water should be read among the unknowns, and appropriate corrections applied. The photocells are subject to "fatigue" when illuminated for a considerable time. It is therefore good practice to leave the lamp on for only a short period, say thirty seconds, while balance is being obtained.

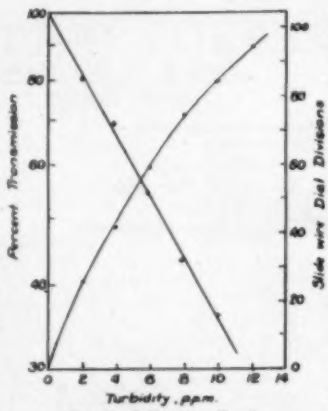


Fig. 5—Calibration Graph

Figure 5 shows the calibration data actually obtained. The curved line, reading on the right hand side of the chart, shows the turbidity corresponding to the slide-wire dial divisions. Since repeated readings on the same sample can be reproduced to within about one division on the dial it is evident that turbidities below 1 ppm. can be read to the nearest 0.1 ppm. The straight line of Figure 5, reading on the left hand side of the chart, is a plot of the percent transmissions on a logarithmic scale of the same standard turbidity samples. Beer's law is closely followed within the range shown.

The photoelectric turbidimeter has been found to be of great practical value in such problems as evaluating the quality of effluent from different filters, and of the same filters under different circumstances such as variations in applied water, filter rates, loss of head, and thoroughness of washing.

J. Doman Joins New Consulting Firm

Joseph Doman, Sanitary Engineer for the Town of Greenwich, Conn.,

since 1941 has left that position to become associated as Sanitary Engineer with the recently organized consulting engineering firm of Hurley, Capocefalo and Associates of 348 Main St., Winsted, Conn. Mr. Hurley is a former governor of Connecticut.

Governor of New Jersey Urging Establishment of State Water Authority

Governor Driscoll, spurred on perhaps by resolutions drawn by the New Jersey section of AWWA, is said to be planning to seek early legislative action creating a State Water Authority. The first project of such an agency would be to complete an earlier proposed Delaware and Raritan Canal Water Supply Project which the New Jersey Legislature authorized in 1948.

The proposed State Water Authority would be further empowered to develop other sources of water for public water supply within the state.

The matter of a State Water Authority has been discussed on various occasions, earlier, but the recent water supply deficiencies in the state has brought the matter to a head. Another reason is the failure of New York, Pennsylvania and New Jersey to come to satisfactory terms on an Interstate Water Compact. In this New York appears to have the "whip-hand" in as much as it controls the headwaters of the Delaware.

Education and Utilization of Sanitary Engineering

In the Public Health Reports Vol. 65, No. 11, for March 17, 1950, appears a report from the Division of Engineering Resources, Bureau of State Services in the Public Health Service. The report deals with "Principles of the Education and Utilization of Sanitary Engineers." Eight principles are set forth as agreed upon by a group of 36 persons representative of both producers and consumers of young men educated in Sanitary Engineering.

To obtain a copy of this report, write to the Supt. of Documents, U.S. Govt. Printing Office, Washington 25, D.C. Enclose 10 cents.

Fred. Ohrt Helps Draft Hawaiian Constitution

Frederick Ohrt, the popular Manager and Chief Engineer of the

Board of Water Supply, Honolulu, T.H., was elected a delegate to the Territorial Convention which convened April 4 in Honolulu to draft an Hawaiian Constitution. The territory is anxiously awaiting action by the U. S. Senate on its bid for statehood. The House of Representatives has already approved admission of Hawaii to the federal union as a state.

Mr. Ohrt, a candidate at large from Hawaii's Fifth Representative District, led a field of ten in the number of votes received. Only five of the ten contenders in the race could be elected.

Many of our readers will remember Fred. Ohrt as a consistent attender of the annual conventions of A.W.W.A.

WATER TREATING EXPERIENCES

Handling Soft Lake Water at Fort Smith, Ark.

The Third of a Series of Articles

by

A. H. ULLRICH,

Superintendent Water and Sewage Treatment

AUSTIN, TEXAS

STUDIES of the Poteau River supply at Fort Smith during the late twenties and early thirties indicated that high salt (chloride) content backwaters of the Arkansas River were becoming more frequent and of longer duration. Since there was no feasible way for Fort Smith (in Arkansas) to control the Poteau River, most of which is in Oklahoma, the city decided to develop an entirely new source of supply. W. R. Holway of Tulsa was retained as consulting engineer to make preliminary surveys for selecting the best available source of supply and, later, to design and supervise construction of the entire project.

The preliminary studies indicated that an impounding reservoir on Clear Creek, a mountain stream near Mountainburg, Ark., would offer the best solution for a new source of supply. The Clear Creek water was of exceptional purity, adequate in quantity and the elevation of the proposed dam site was such as to make gravity flow into the city feasible. Based on Mr. Holway's recommendations, Fort Smith voted the necessary revenue bond issue to finance the construction of a dam on Clear Creek, a new and modern purification plant to treat the lake water and a pipe line to conduct the treated water into the city. The project also included strengthening the distribution system in the city and covering the then existing high elevation filtered water storage reservoirs within the city limits. Actual construction was started in 1935. The entire project was finished and placed in operation during May, 1936.

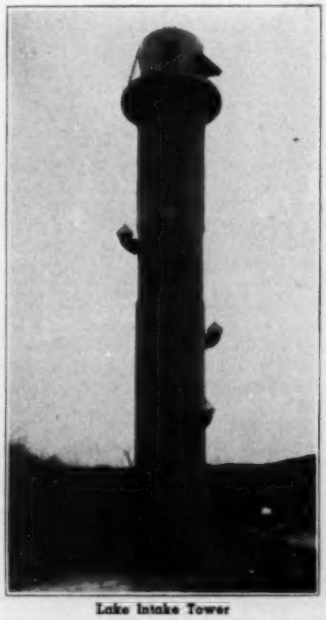
Influence of Drainage Area on Water Quality

The entire drainage area of Lake Fort Smith, is in the Boston Mountain range of the Ozarks. A large percentage of the area is wooded, the soil is rocky and generally unsuited for agriculture. There are no limestone out-croppings in the drainage area and hence the water is very low in alkalinity, low in bicarbonate hardness and has a low pH. There are a few low grade manganese ore outcropings in the immediate lake area

The Author

which are responsible for the few tenths of a part per million manganese in the lake water during turn over periods. Turbidities of the raw lake water are generally low, although heavy rains have caused turbidities as high as 1,600 ppm. The turbidities which are encountered are normally very fine and colloidal in nature. It is likely that the low alkalinity and low pH together with the fineness of the turbidity are all factors which cause the turbidity to stay in suspension. At any rate, there is very little silting in the lake except at the extreme upper end, where heavy material is deposited. Fortunately the creek above the lake usually clears very rapidly after a heavy rain and this clear water then displaces the turbid water by pushing it over the spillway. For this reason the upper level of lake water is usually quite clear by mid June and heavy algae growths may be expected in this level during the remainder of the summer.

Having heard Mr. Ullrich speak on various occasions, the editors realized that he is well qualified to present to the readers of *Water and Sewage Works* a series of articles discussion some of his varied experiences in treating waters of vastly different characteristics.



Lake Intake Tower

Intake Gates at 7.5-22.5-37.5 ft. Below Spillway Level.

Since there are few soluble minerals in the drainage area the lake water is low in total dissolved solids. The following table gives the minimum, maximum and average values for the more common constituents of the raw lake water for which routine tests were made in 1946:

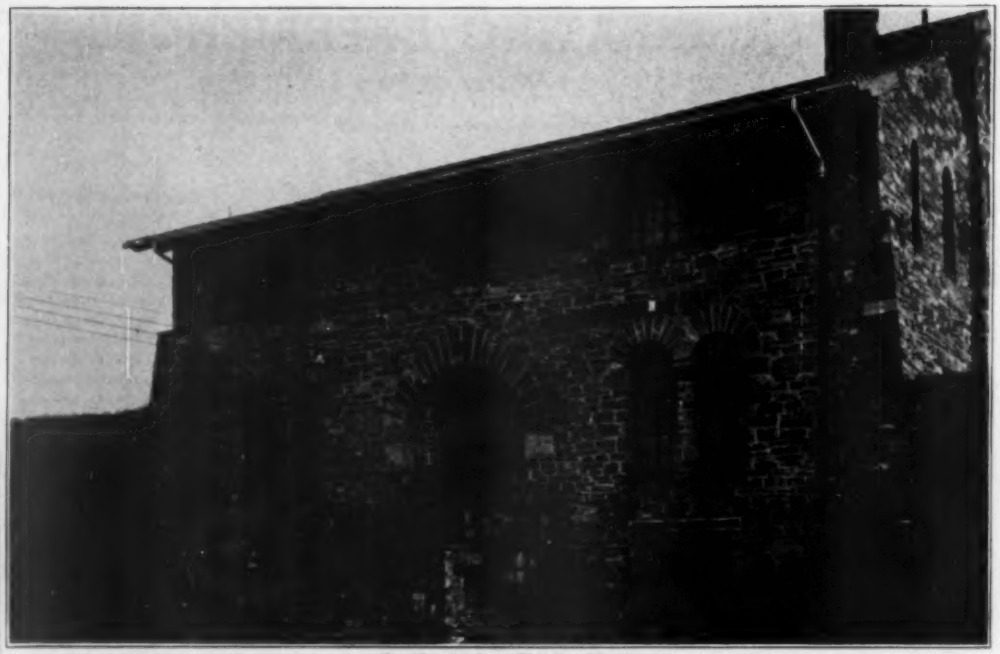
PARTS PER MILLION

	Minimum	Maximum	Average
Total Alkalinity	10.0	23.0	13.8
Total Hardness	14.0	27.0	20.2
Chloride	3.8	4.0	3.9
Iron (Fe)	.01	.2	.1
Manganese	0.0	.4	.2
Turbidity	10.0	850.0	52.2
pH	6.1	7.1	6.7

A TYPICAL QUALITY OF THE TREATED WATER IS REVEALED IN THE FOLLOWING ANALYSIS

	PPM
Silica (SiO_2)	4.3
Iron (Fe)	.04
Aluminum (Al)	.2
Calcium (Ca)	10.0
Magnesium (Mg)	1.5
Sodium (Na)	1.4
Potassium (K)	1.2
Carbonate (CO_3)	4.0
Bicarbonate (HCO_3)	16.0
Sulphate (SO_4)	12.0
Chloride (Cl)	4.5
Fluoride (F)	0.0
Nitrate (NO_3)	1.4
Total dissolved solids	51.5
pH	8.6

The following table gives the minimum, average and maximum values for some of the routine tests made on the treated water in 1946:



The Mountainburg Filtration Plant

Originally 6 MGD Capacity Increased in 1943 to 9 MGD; Amongst Earliest to Install Surface Filter Wash System and Porous Plate Filter Bottoms.

PARTS PER MILLION

	Minimum	Average	Maximum
Total Alkalinity	13.0	20.0	36.0
Total Hardness	29.0	45.5	66.0
Dissolved Oxygen	2.0	7.4	11.5
pH	8.0	8.6	9.6

Influence of Lake on Water Quality

Lake Fort Smith is quite small in that its storage capacity is only 3.9 billion gallons. However, the average annual rainfall from 1937 to 1946 inclusive, was 48.34 inches so that the slightly more than 74 square miles of drainage area has furnished a more than adequate supply of water. It is interesting to note that the minimum annual rainfall during this period was 36.41 inches in 1940 and the maximum was 75.81 inches in 1945. While the lake at spillway elevation covers only 438.2 acres and it is only 2.5 miles long it is quite deep for a lake so small in size, being 65 feet deep at the intake tower when full to the spillway elevation.

The lake depth of 65 feet is sufficient to cause definite temperature stratification of the water. During the summer months water temperature variations from 84 F at the top to 52 degrees F at the bottom are common. Since the intake tower has three fixed intake valves located at effective depths of 7.5 feet, 22.5 feet and 37.5 feet below the spillway elevation it is usually possible to obtain summer water temperatures of 84 degrees F from the top valve, 64 degrees F water from the middle valve and 54 degrees F water from the lowest valve. In addition to the temperature variations there may also be variations in other characteristics such as the pH, alkalinity, turbidity and algae growths. Usually, during midsummer the pH of the upper level water may increase to 7.0 or even to 7.1 while the pH of the lower level water will be only 6.1. Conversely, the turbidity of the upper level water may decrease to 2.0 ppm., while the lower level water is still 10.0 ppm. or greater. Likewise, when the turbidity of the upper water becomes low the algae growths there may become heavy while such growths are still almost entirely absent at the lower levels.

The question of whether or not there is an advantage in having intake structures which permit the drawing of water from different elevations has frequently been raised. In the author's experience the answer has always been yes. As noted in a previous article, at the old Poteau River plant at Fort Smith water was always taken through the upper intake valve during high river stages to avoid the higher turbidities of the lower water. At the Lake Fort Smith plant the procedure was usually to take water from the upper valve after the fall lake turnover period and during the winter and spring months when there was a possibility of the upper water having a slight advantage in lower turbidities. Later, as the turbidity of the upper water decreased and algae growths in it became troublesome it became standard practice to take water from one of the lower valves in order to avoid the algae. Due to its higher turbidity, lower pH and lower temperature the lower level water is more difficult to coagulate and settle but the increase in coagulant cost is more than offset by the saving in activated carbon and longer filter runs.

THE FILTRATION PLANT

The Lake Fort Smith plant is a modern treatment plant designed for coagulation, settling and filtration. The original plant had one over and under baffled quick mix unit, two Infilco Supermix Flocculators, two settling basins, four 1.5 MGD filter units and clear well of 11 MG capacity. Later one additional settling basin and two additional filter beds were added.

The original Infilco Supermix flocculation units had seventeen sprockets and five chains in each unit, all submerged and operating in soft, low

pH water. Sprocket and chain failures were frequent so the units were rebuilt to eliminate all but five submerged sprockets and two submerged chains. Sprocket and chain failures, while less costly, were still troublesome so dry wells were built at one end of each flocculator tank, stuffing boxes were installed in the tank walls and the paddle shafts were extended through the stuffing boxes to permit the use of oil lubricated chain drives. This solved the excessive cost and troublesome upkeep of these mechanical mixers. At the time when the Lake Fort Smith plant was built (1935) it was common practice to use submerged driving mechanisms in mechanical flocculators. Many of the manufacturwers of this type equipment later changed to a dry well, oil lubricated drive design.

The original filters were equipped with conventional perforated cast iron underdrains with the filter sand supported by the usual graded gravel layers. Since the plant was designed for coagulation and filtration and no softening was involved the filter sand selected was quite fine, having an effective size of approximately 0.45 mm. These filters did an excellent job of filtering but since, as will be noted later, the water was difficult to coagulate and settle, we soon experienced trouble with mud ball formation. After trying various chemical cleaning methods without success, we installed a Bayliss type surface washing system on an experimental basis, in one-half of one filter. This worked so well in breaking up the mud balls which had started forming that Bayliss type surface washing systems were installed in all the filters. Other type surface washing systems were ruled out in our case because we had only low pressure water from our wash water tank available and we did not wish to install a booster pump for this purpose only. In our opinion the Bayliss system has the advantage of working well with low pressure water and of giving good coverage in any shape filter box. It does have the disadvantage of requiring a great deal of pipe work.

Air Binding and Bed Inversion Troubles

Before we learned to avoid the high algae concentration water in the summer season by changing to lower level lake water we experienced considerable trouble with light, fluffy algae floc carrying over to the filters. This, of course, caused rapid filter clogging and, if the filters were not washed before excessive loss of head build up, a partial vacuum or negative head would result in the underdrains. Since the upper level lake water is normally high in dissolved oxygen (air) these negative heads would "pull" air out of the water and cause air binding. Then if the operator became rushed or too impatient and failed to work the air out of the bed slowly, and failed to use caution in opening the wash water valve in the washing operation, there was great danger of disrupting the entire filter bed. On one occasion when the author inspected the plant early one morning he actually found a large circular coating of sand on the ceiling above the filter. On questioning the operators he learned that the night operator had permitted the filter to become completely airbound, had taken the filter out of service for washing, had opened the wash valve too rapidly and, to his amazement, had blown some sand all the way to the ceiling. Needless to say, the operators had been instructed differently but apparently these things do happen. At any rate we suspected that there had been a good deal of mixing of gravel with our sand during the first summer the plant was in operation. This suspicion was confirmed both by inspection of the filter beds and by the fact that some of the filters began to pass sand through their underdrains.

Porous Plate Bottoms Installed

Continued trouble with air binding and the possibility of mixing the various sizes of filter media during washing led us to replace the original underdrain with Aloxite Brand Porous Plates in one experimental filter in

Fort Smith's Mountainburg Filtration Plant
Original Infilco Supermix Flocculators and Settling Basins Beyond.

Fort Smith's Mountainburg Supply Line
Bitumastic Lined 27" Steel Pipe—23 Miles of It.—Brings Soft Water to Town.

1941. The original sand in this filter was saved when it, together with the gravel and underdrain laterals, was removed. All the gravel was screened out and the sand was then placed on top of the newly installed plates. After the change to porous plates this filter gave excellent service and on the strength of its trouble free operation the two additional filters installed in 1943 were equipped with porous plates. Recent reports received from Fort Smith indicate that they are still enthusiastic about the trouble free operation of all the porous plate filters. The author's experience with these installations has convinced him that porous plates have definite advantages when used with a non-incrusting water.

In the next article of this series the author will discuss the treatment methods used with the soft Lake Fort Smith water.

Credit to Whom Credit is Due

On page 122 of our March issue appears a useful graph for determining the proper dilution of samples in the 5-day B.O.D. test.

This graph was offered for publication by John R. Wolfe, Asst. Sanitary Engr. of the Ohio Dept. of Health. In his letter, accompanying the graph it was requested that credit for the development of the graph be given the Ohio Dept. of Health Laboratory and not the Engineering Division. This we regret was not done through oversight.

Danse Warns Not to Expect Federal Assistance on Sewerage Financing

L. A. Danse, Chairman of General Motor's Industrial Waste Control Committee, and also member of the Federal Water Pollution Advisory Board, has been advising communities and all concerned that it is futile to look for any financial handouts from Uncle Sam in connection with sewage disposal problems.

Danse said, "It's cheaper to do it yourself. The money comes from you in the first place and Washington takes its cut on every dollar distributed as a grant before it gets back to you."

Danse also is warning that delays will prove costly because—"The laws are accumulating more teeth. You are growing all the time, and your problem is getting bigger the longer it is left unsolved."

Mr. Danse, as a member of the Federal Water Pollution Advisory Board, should know whereof he speaks.

Edward S. Cole Dies in 79th Year

Founded The Pitometer Co. of N.Y. and London After Inventing the Pitometer

Edward Smith Cole died on March 18th in his Upper Montclair, N. J., home. He was 78.

Mr. Cole, a member of the Am. Society of Civil Engrs., an Honorary Member of the American Water Works Association, fellow of the American Society of Mechanical Engrs., and recipient of its Worcester-Reed-Warner Medal, was best known in the engineering field for his invention of the flow measuring "Pitometer," the "Cole Recorder," and the "Pitometer Log," which was successfully used on warships for recording the speed and distance travelled by ships of the U. S. and British Navies.

Mr. Cole attended the Univ. of Illinois and, later, Cornell University from which he received his engineering degree in 1894. His first job was on the construction of the Chicago Water Works in 1894, as assistant to his father, John Adams Cole, who was construction engineer on the project. In 1896 he conceived of and perfected the "Pitometer" for measuring the flow of water through pipe lines under pressure. This development represented the first practical adaptation of the principle of the long known Pitot Tube, which was also to prove of commercial importance. Cole's new flow measuring instrument was first used in connection with a survey of the water distribution system of Terre Haute, Ind., to detect and locate water losses through hidden leaks and illegal connections. After this successful demonstration, the use of the "Pitometer" rapidly gained recognition and prominence in diagnosing defects in water systems, low pumping efficiencies, extent of friction losses, etc.

In 1904 Mr. Cole founded The Pitometer Co. of N. Y. City and in 1927 established a subsidiary company in London. He served as president of both companies until 1947 when he retired. He leaves his widow, a daughter and two sons, one of which, E. Shaw Cole, is Chief Engineer of The Pitometer Co.

Short Course on Flow Measurement

The Department of Civil Engineering and Extension Services of the Pennsylvania State College has announced a Short Course on Flow Measurement for Civil, Sanitary, Mechanical Engineers, Municipal Engineers, and representatives of manufacturers of instruments, etc.

The staff will be headed by Dr. Andre L. Jorissen, Assoc. Prof. of Civ. Engineering as Course Chairman. The course will be held from June 5 to 15, entrance fee $25 plus living expenses. For further information write to Dr. Andre L. Jorissen.

M.I.T. Announces Improvement in Beet Sugar Manufacture

Will Reduce Waste Load Appreciably

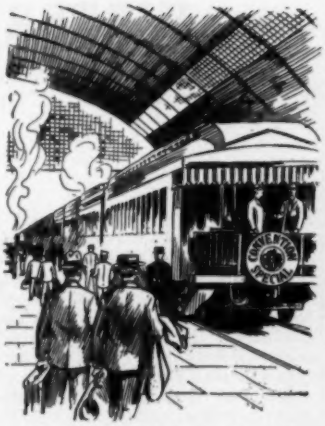
According to an announcement from Mass. Inst. of Tech., Dr. Clair N. Sawyer, Assoc. Prof. of San. Chem., and Dr. E. A. Pearson, now of Univ. of Calif. have developed a new process of waste treatment which will make an important improvement in the efficiency of manufacture of beet sugar. The new waste treatment process increases the yield of sugar from every ton of beets by about four pounds and at the same time reduces water consumption by at least 320 gal. per ton.

The process involves the treatment of waste waters with chlorine to destroy bacteria in the mill's process water. This allows for a rapid separation of non-sugar impurities. The small concentration of valuable sugar which remains in the chlorine treated water can be recovered since that water can be re-used for sugar extraction instead of being discharged to waste.

Studies by Dr. Sawyer indicate that the savings during the first year should be sufficient to pay for the cost of the new treating equipment.

Federal Loans For Public Works

Included in the first approvals of applications for Federal loans to be used for plan preparation of State and local public works, were 25 sewage treatment plants and collection systems, five of which will cost more than $1 million each. One sewer system will run more than $4 million and two will cost about $3 million.



A.W.W.A. Convention Bound
See you in "Phila." May 21-26

CHART FOR CALCULATING CIRCULAR EXCAVATIONS*

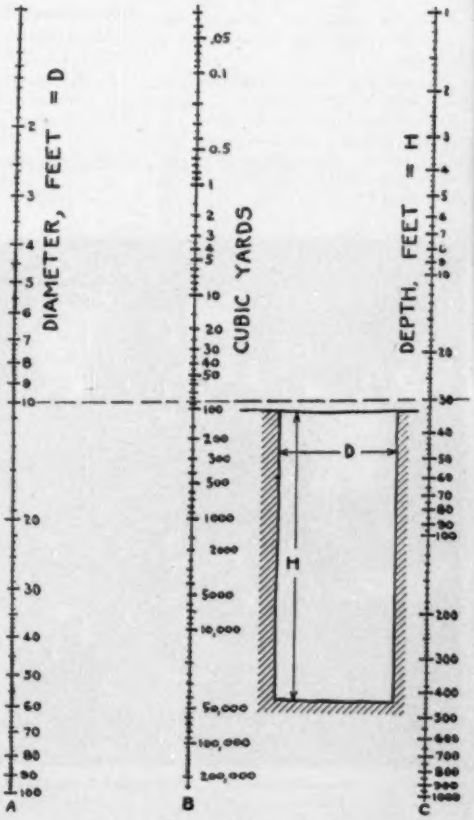
This chart will be found handy for determining the yardage in circular excavations such as circular pits, cellars, wells, shafts, etc. It gives the amount of space occupied by circular tunnels or sewers or anything of that sort. Its application to circular excavations is practically unlimited. Simply lay a straightedge across the chart and column B immediately gives the yardage.

For example: How many yards must be excavated to make a pit 10 ft. in diameter and 30 ft. deep?

Connect the 10 in column A with the 30 in column C and column B at once shows the yardage to be very close to 87 cubic yards.

The chart will be found to be sufficiently accurate for nearly all work of this nature, and the range of the chart is wide enough to include nearly every size of circular excavation ever made, or likely to be made.

*Contributed by W. F. Schaphorst, M.E., Newark, N.J.



He Couldn't Go to the Convention
(Courtesy the Canadian Section)

WATER MAIN STERILIZATION

Some Notes on Procedure and Special Equipment

by
HENRY F. MUNROE
Chemical Engineer
% PROPORTIONEERS, INC. %
PROVIDENCE, R. I.

THE recent drought in the Eastern States and the expanded program of water main extensions now being executed by numerous water works has brought renewed attention to the disinfection of new and old mains. The many requests for exact information on main sterilization indicate the need for a review of the subject. It is the intention of this paper to review main sterilization; the need, the procedure, and the available equipment.

Water pipe laying on the ground before installation in a trench is subject to many possibilities of contamination. Also, there is always great possibility of contamination while the line is being made up. One cannot predict when undesirable bacteria are in the soil of the trench, nor can one predict the quality of the water that may find its way into the open end of the pipe.

Recognizing these probabilities, the American Water Workers Association has developed an excellent procedure for the disinfection of new and repaired water mains. *"A Procedure for Disinfecting Water Mains 7D.2-1947"*[3] is available from the

The Author

American Water Works Association, 500 Fifth Ave., New York 18, N. Y. This method has been developed by a committee with years of experience in the disinfection of water mains, and the publication should be considered highly authoritative.

Recommended Procedure

An outline of the recommended procedure of A.W.W.A. is:

1. Keep interior of pipes clean. (a) Free of all foreign matter. (b) Swab interior with an effective bactericide. (c) Block open ends to prevent trench water from entering pipe.

2. Joint packing materials (in order of preference). (a) Solid molded or tubular rubber rings. (b) Asbestos rope. (c) Treated paper rope. (d) Braided cotton. (e) Hemp and jute.

3. Before disinfection, main flushing to take place (after pressure test) at velocity of at least 2.5 feet per second.

4. Chlorination. (a) Chlorine or chlorine-water. (b) Chlorinated lime (stabilized-high-test calcium hypochlorite, such as "HTH," "perchloron," "Pitchlor," etc.). (c) Liquid sodium hypochlorite.

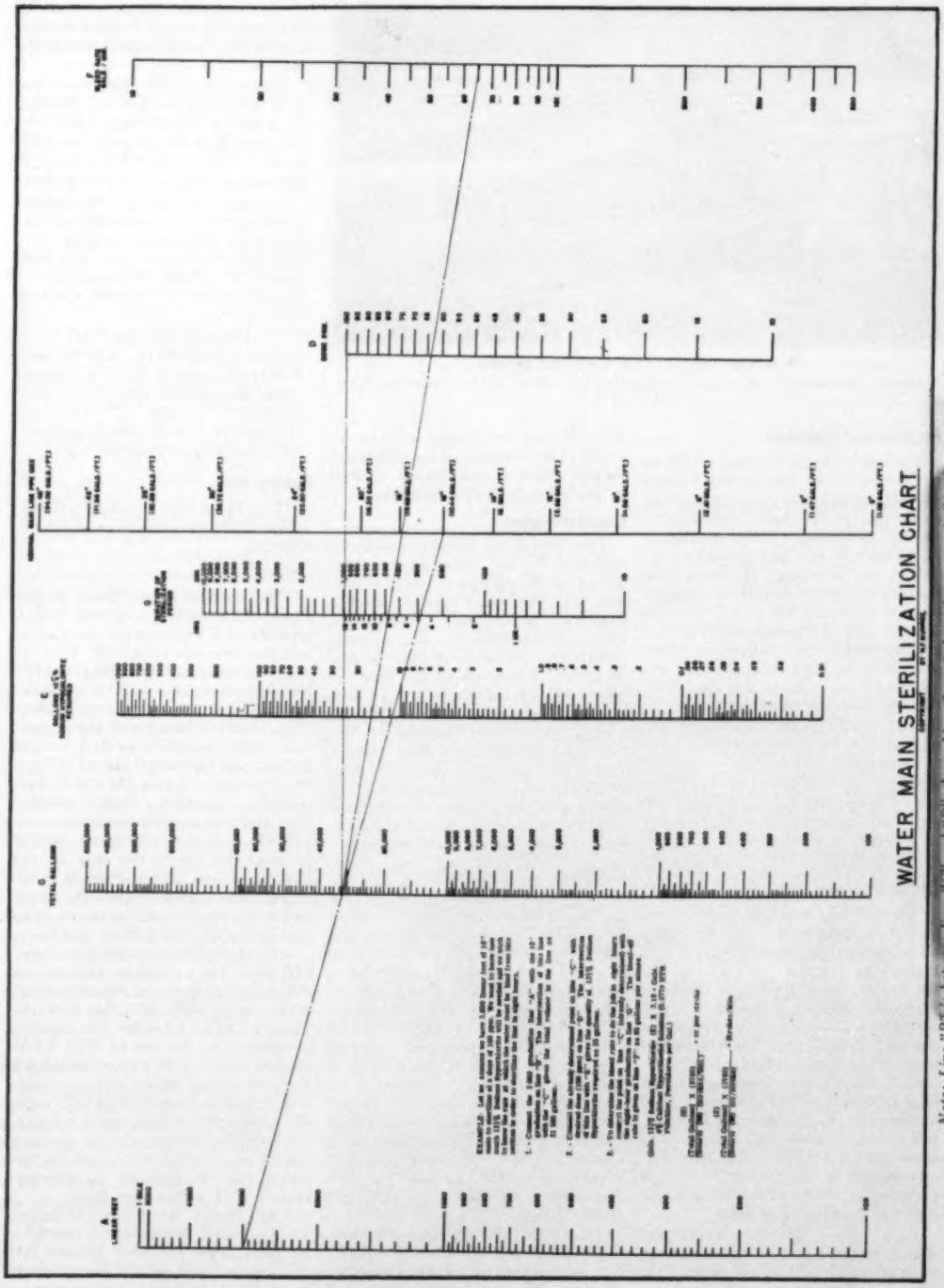
5. Point of application to be at one extremity of pipe section with bleed to be at opposite extremity of properly segregated section. Precautions to be taken to prevent water from flowing into potable supply. (a) Injection of chemicals to take place through corporation or cap-cock inserted in the line for that purpose. (b) All high points on section treated to be properly vented for air escape. (c) Rate of application to be such as to give a uniform dose of at least 50 ppm at end of section of main being treated.

The above outline mentions briefly the important points of main disinfection. Obviously the entire procedure should be carried out under the direction of a competent supervisor.

Most of the above procedure requires no further explanation. However, for review purposes some will be briefly discussed.

Mention has already been made of several of the sources of contamination or re-contamination. An outstanding possibility of contamination is the joint packing material used. Some years ago Adams and Kingsbury[2] of the Massachusetts Department of Health conducted extensive experiments on the contamination of water lines by hemp and jute joint packings. The growths of bacteria after short soaking periods in the laboratory were astounding. An involved treatment, not easily followed in routine practice, was required to sterilize this packing. For this reason hemp and jute have been placed at the end of the list of available packing materials. As a matter of fact these two materials have been omitted from the recently revised "Specifications for the Laying of Cast Iron Pipe" of the A.W.W.A.

Emergency Set-up of Portable Dual-Drive "Chlor-O-Feeder."
A Multi-purpose Feeder Ideal for Water Main Sterilization.



Note: Line "B" is between lines "C" and "D". In making the cut of maximum permissible size the letter "B" was sacrificed.—Ed.

WATER MAIN STERILIZATION CHART.

Developed by the Author to Eliminate Computations in Main Sterilization Problems.

"Rate-Setter" for Attaching to Bleed-off Hydrant.
Eliminates Guesswork in Adjustment of Flow Rate and Chlorine Dosage into Main Being Chlorinated.

Preliminary Flushing

The purpose of flushing prior to sterilization is to remove the foreign material that usually finds its way into a new or repaired main. Actual practice has determined that a velocity of more than 3 feet per second is required for scouring; therefore, the flushing procedure should be arranged to give a velocity of 3 to 7 feet per second. The chart presented with this article reveals the volumes of water in gallons per linear foot for the various pipe sizes. From this the bleed rate to obtain the recommended flushing velocity of 3 feet or more per second can be easily calculated.

(*Example*): For a 24" main on scale "B" of the chart (5th from left) each foot contains 23.5 gals. For the minimum velocity of 3 ft./sec. the flow must be at least $23.5 \times 3 = 70.5$ gal./sec. or $70.5 \times 60 = 423$ gals./min.

Chlorine Dose

The actual dose of chlorine required depends upon: (a)—the probable degree of contamination; (b)—type of packing used; (c)—the pH of the water. Usually the dose must approximate 100 ppm in order to secure a residual of not less than 55 ppm at the end of the line. A main installed in an area where unsanitary conditions prevail will, of course, require a larger dose of chlorine than others. Also, if packing material is used that may harbor and sustain bacteria, a larger dose should be used and the detention periods should be designated "with full pressure applied" to force the solution into the packing if possible.

It is known that the degree and speed of disinfection by chlorine is affected by the pH of the water. Increasing alkalinity of water requires a longer period of contact, or a higher dosage. These factors should be considered when the dosage is being selected. The efficiency of the procedure should, wherever possible, be checked by bacteriological examinations.

Contact Period

The period of contact should be governed by the same factors that determine the dosage. If there is preliminary evidence of contamination a prolonged period, such as 72 hours, should be considered. The average sterilization period is between 24 and 48 hours. Inasmuch as the final removal of the chlorinated water does not involve any other factors than reducing the chlorine content to that commonly used in the finished potable water, the rate of removal of chlorinated water is not important. The line should be bled, however, until the chlorine residual approaches that normally carried in the water system.

Calculations Involved

The uniform application of the sterilizing solution involves the calculation of the gallonage of the pipe line from the size of pipe and length of line to be sterilized. The calculation of the amount of hypochlorite required is determined from the selected chlorine dosage, the available chlorine content of the hypochlorite solution and the bleed rate. In addition, it is necessary to know the duration of the bleed-off period so that the chlorine dosage may be carried to the extremities of the main. The accompanying alignment chart will prove useful in making all of these calculations. The following is an example of how the chart is used.

(*Example*): Let us assume we have 3,000 linear feet of 16" main to sterilize with a dose of 100 ppm available chlorine. We want to know how much 12½% sodium hypochlorite solution will be needed. We also wish to know the rate at which the water must be bled from this section in order to sterilize the line in eight hours. Using the chart—

1—Connect the 3,000 graduation line scale "A" with the line for 16" pipe on scale "B"—fifth from left. The intersection of the diagonal line with scale "C" gives the total volume in the section of main as 31,500 gallons.

2—Connect the already determined point on the "C" scale with the desired dose (100 ppm) on scale "D". The intersection of this line with scale "E" gives the quantity of 12½% sodium hypochlorite required as 25 gallons.

3—To determine the bleed rate to do the job in eight hours, from the same 31,500 gal. point on scale "C" extend a line through the eight hour point on scale "G" to scale "F". The point of intersection at 65 gallons per minute is the proper bleed-off rate.

Equipment

Three factors are involved in the selection of the equipment for main sterilization.

Capacity

The standard Heavy Duty Midget Chlor-O-Feeder has a normal design capacity of 5.5 gallons per hour at an injection pressure of 85 psi. This capacity is obtained by using a 1725 RPM electric motor, a 50:1 speed reducer and a three-step cone pulley. The above combined with the adjustable stroke length from 0.05 to 0.20 inches gives the design rate of 5.5 gallons per hour. When this unit is particularly adapted for main steirilization, and it is desirable to increase the delivery, a lower ratio speed reducer is employed, or in the case of the gasoline driven unit it is simple to increase the engine speed. By these means the capacity can be increased to approximately 8.5 gallons per hour.

The High Pressure Midget Chlor-O-Feeder has a nominal capacity of 5.5 gallons per hour at injection pressures up to 200 psi. As with the Midget Chlor-O-Feeder this capacity is obtained by the use of 1725 RPM electric motor, a 50:1 speed reducer, a three-step cone pulley and a variable stroke length from 0.05 to 0.75 inch. By using a lower ratio speed reducer, or increasing the speed of the gasoline engine of the dual drive unit the capacity can be increased to approximately 8.25 gallons per hour.

The Model 47 Chem-O-Feeders have nominal capacities of multiples of 8.0 gallons per hour against 100 psi, depending upon number of heads involved. A built-in speed reducer, a 1725 RPM electric motor and an adjustable stroke length of from 0 to

0.250 inches are employed. The capacity of the Simplex Unit can be increased to approximately 12 gallons per hour by using a high delivery cam; or, when the gasoline engine-driven unit is furnished, by increasing the engine speed. The Model 47 Chem-O-Feeders are available in Duplex and Triplex styles which deliver 24 to 36 gallons per hour at pressures up to 125 psi.

The Automatic and Proportional Chem-O-Feeder is a unit used for sterilizing mains requiring no outside power whatsoever. Power for operating the feeder is taken from the main itself. The feeding system consists of a disc meter installed in a temporary by-pass line around the segregating gate. This disc meter drives a pilot valve in strict proportion to the flow. The pilot valve transfers water pressure to one side or the other of an actuating diaphragm which in turn motivates a second diaphragm that actually pumps the hyochlorite solution into the by-pass line. This type of unit has been made up into a compact assembly and is extensively used for emergency work. Holton[4] used it extensively in Providence after a bacteriological check-up of new mains showed sterilization to be required.

Line Pressures

The regular diaphragm feeders are available for pressures up to 85 psi for the Heavy Duty Midget Chlor-O-Feeder and a maximum of 100 to 125 psi for the Model 47 Chem-O-Feeders. For higher pressures up to 200 psi the High Pressure Midget Chlor-O-Feeder is used. The high pressure unit uses a stainless steel piston and a high pressure plastic cylinder.

Operating Power

If the main to be sterilized is in the built-up section it may be possible to use a source of 110/220 volt, 60 or 50 cycle, single-phase current for operation of the feeder motor. Where such current is not readily accessible a small portable gasoline motor can be used.

Rate Setter

The importance of having a uniform dose throughout the new line was previously mentioned. This is accomplished by injecting the chlorine solution continuously at one extremity while a certain amount is bled off at the other extremity. In order to be certain of a reasonably uniform dosage a definite bleed-off rate must be established. While there are a number of formulae for estimating the discharge from open nozzles, the flow Rate Setter as manufactured by %Proportioneers% Inc. facilitates this procedure, inasmuch as a flow gauge (reading directly in gallons per minute) is attached to the bleed-off hydrant nozzle. The Rate Setter consists of a National Standard hydrant coupling at one end, a replaceable fixed orifice at the other end and a direct-reading flow gauge for determining the flow from the hydrant in gallons per minute. This converts the complicated problem of estimating or calculating the flow to a simple procedure easily followed by anyone.

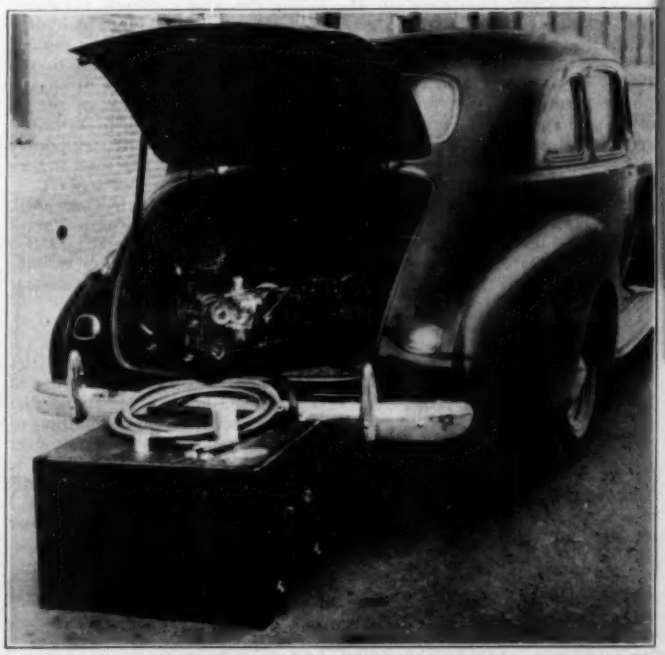
Other Methods

The previously outlined procedure constitutes good water works practice, but is by no means the *only* system used. Holton[4] solved a main sterilization problem in Providence, R.I., by sterilizing the new main as it was made up day-by-day. This problem involved the sterilization of a 12-inch high-service main, which was to replace an 8-inch main in accordance with the recommendations of the National Board of Fire Underwriters. As the section was all in ledges, it was decided to use the trench previously occupied by the 8-inch main. Since the replaced sections were immediately placed into service another system of sterilization was used. A pitot tube and manometer were employed on the feeder main to determine the rate of flow through the new main and to calculate the amount of sterilizing solution to dose at 0.25 ppm. Bacteriological samples collected while the main was being replaced showed no positive results and the sterilization was continued for five days after the job was completed. Since no positive results were obtained from the bacteriological tests the treatment was considered effective and the equipment removed.

Heller[5] employed a similar scheme later on, in which small chlorine doses (0.5-2.0 ppm) were applied for 2 to 3 months while the water was used for other purposes than drinking. For installations where the water is not to be immediately used for drinking this method may be considered. In any event, the effectiveness of all methods of sterilization should be checked by bacteriological examination before permitting the water to be used for human consumption.

Main Sterilization Specifications

Upon completion of installation and testing of any portion or the whole of the main, the new work shall be sterilized under the supervision of a representative of the engineers, the owner, or a company practicing main sterilization, in the following manner:



Multi-purpose Engine Driven Dual "Chlor-O-Feeder."
Showing Carrying Case and Accessories for Main Sterilization or Emergency Chlorination.

The pipes shall be thoroughly flushed to remove loose dirt or foreign material. Rate of flushing shall be sufficient to provide a velocity in the line of three to seven feet per second. Water for flushing and sterilization will be furnished the contractor by the owner without charge.

A sterilizing agent consisting of 12½% sodium hypochlorite solution, containing not less than one pound of available chlorine per gallon of concentrate, or a prepared solution of high-test calcium hypochlorite, which contains approximately 70% available chlorine, shall be injected into the main.

The pipe shall be bled at one extremity while injecting the chlorine solution at the other end, long enough to impart a chlorine content of 50 to 100 ppm of available chlorine by weight throughout the section.

After the line has been completely filled with the sterilizing solution full operating pressure shall be imposed, and the section allowed to remain under treatment for a period of not less than 48 hours.

The main shall then be flushed free of all traces of sterilizing solution, or until the bleed-off water has the same chlorine residual as is normally carried in the system. Upon completion of the sterilization and flushing, the sterilized line shall be sampled and analyzed by an experienced bacteriologist and placed in service upon receipt of his written approval of the water. If the results are not satisfactory the sterilization procedure must be repeated.

Consult the Literature.

When developing a department practice or procedure, it is always of value to review the experiences of others in the same line. References to the literature givn below is included to assist in such an investigation.

1.—Calvert, Cecil—Main Disinfection JAWWA 40,2 125 (1948)
2.—A Procedure for Disinfecting Water Mains 7D.2 (1947)
3.—Adams, G. O. and Kingsbury, F. H.—Experiences with Chlorinating New Water Mains JNEWWA 51:2:60 (1937)
4.—Holton, Phillip V., Jr.—Chlorinating New Mains—Water Works Engineering (February 14, 1940)
5.—Heller, A. N.—Proposed Plant for Water Main Sterilization JAWWA 35:2:168 (1943)
6.—Smith, Fred E.—Chlorination of a Cambridge Main JNEWWA 51:2.57 (1937)
7.—Weir, W. Victor—Emergency Repairs of Distribution Systems JAWWA 34:8.1205 (1942)
8.—Armbrust, H. N.—Emergency Equipment for Sterilization and Its Application—Jour. Main Water Utilities Association (1941)
9.—Moore, Charles R.—Chlorination; Routine and Emergency Water Works and Sewerage (March, 1943)
10.—Shaw, Percy—Cleaning, Sterilizing and Incorporating the Amoskeag Mills Water System into the Manchester, N.H. City System JNEWWA Vol. LVI.#2:212 (June, 1942)

Engineering Papers of Hydraulic Institute—Vol. II

The Hydraulic Institute, a trade association of pump manufacturers, has announced the publication of a group of engineering papers on subjects pertaining to pumps.

Under the title, "Engineering Papers of Hydraulic Institute—Vol. II, this volume contains four papers which won awards in various engineering contests sponsored by the Institute. These papers include "Cavitation in Centrifugal Pumps" (Stepanoff); "Centrifugal Pump in the Process Industries" (Nielson); "Operation of Centrifugal Boiler Feed Pumps" (Gartmann); "Submergence for Centrifugal Condensate Pumps" (Waldo).

Copies of this publication may be secured from the Hydraulic Institute, 90 West St., New York 6, N.Y., at $2.00 per copy.

Puerto Rico Aqueduct Authority Awards Contract for Dam

As part of the elaborate plan to bring water to Puerto Rico, the Puerto Rico Aqueduct and Sewer Authority has announced the award of a $2,131,600 contract for the construction of the Loiza Dam. This will be part of the Rio Grande de Loiza water supply development program launched two years ago.

Construction of the dam was scheduled for March and planned for completion in 1952. This initial development, according to Sergio Cueva, Exec. Dir. of the Authority, will add 30 mgd. to the present sources of supply. Buck, Seifert, and Jost are the consulting engineers and Sumner S. Sollitt & Co. of Chicago will be the contractors.

The pipe line, pumping station, and filtration plant will be put into operation within the next sixty days. When the dam is complete, the Loiza reservoir will have a capacity of 6.5 billion gal. and minimum regulated flow will exceed 100 mgd. A hydroelectric plant and pumping station will be constructed adjacent to the dam to carry the water from the reservoir through 17,000 ft. of 48-in. transmission main to filtration plant. Meantime the temporary pumping station will be used to permit operation of the filter plant.

When this project is completed, it will be a major step in Puerto Rico's program for a $35,000,000 aqueduct and water service extending throughout the Island.

Statistics Show

A speaker was citing statistics which proved the greater docility of the well fed human. He stated that it was a fact that the committing of violence against persons hardly ever occurs after a hearty meal.

Some wag leaned over to his neighbor and said—"Now, brother, I know why so many after-dinner speakers are still alive!"

A Smile vs a Frown

Didya Know—it takes three times as many muscles to frown as it takes to SMILE.

Pump Handbook

"Pump Handbook" is as its name implies a handbook of pumps and pumping. It was written by Volney C. Finch, Prof. of Mechanical Engineering, Stanford University, Palo Alto, Calif. Prof. Finch says that he wrote the book "as a crusade against the regrettable waste of power found in water and sewage works pumping." In 202 pages of specialized information, the author has emphasized selection, installation, operation, and maintenance practices that can reduce pumping costs.

Twenty-three chapters and an Appendix cover the entire subject of pumps and pumping through all phases: type of pump, design formulas, installation and operation, type of service, etc. The appendix alone contains 40 pages of hydraulic tables and pump data. This book is a must for any engineer who has a pumping problem, or operates and maintains a pump installation.

Published by the National Press, Millbrae, Calif., the book retails at $4.00 per copy.

Something to be Added to Lansing Sewage Plant

At Lansing, Mich., when high school students took over the city government for a day they made several suggested improvements among which was that of installing automatic perfume atomizers in the Sewage Treatment Plant. Another was that a new jail be built with a television set in each cell.

CALCULATOR FOR COMPUTING I^2R QUICKLY

By V. W. PALEN*

Westinghouse Electric

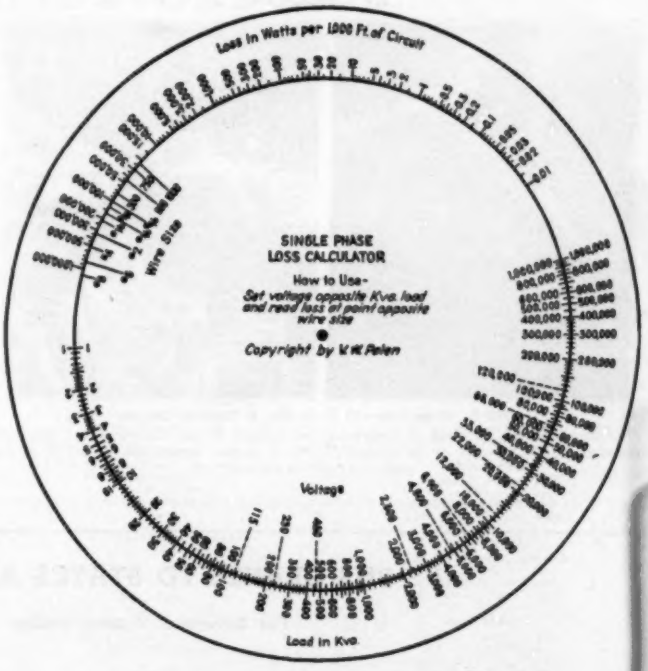
EAST PITTSBURGH, PA.

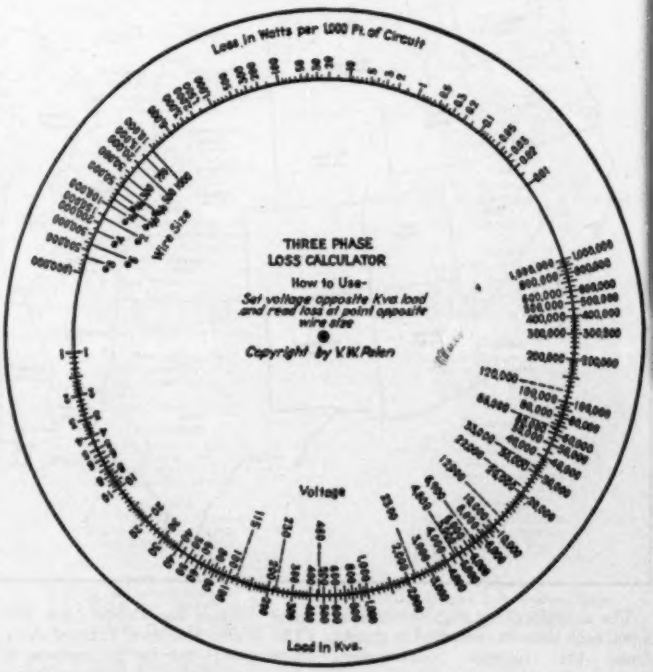
HERE'S a device which determines I^2R loss in wire circuits with a flick of the finger. The accompanying cut supplies the necessary parts. Cut along the circles of each of the illustrations to make two discs and two rings. Using rubber cement, mount the discs on separate pieces of cardboard—on reverse sides of a third piece of cardboard mount the two rings. Now punch the center holes and insert a small brass bolt to hold the discs in place. Washers will help to prevent wear and tear on the paper. Tighten the bolt to provide the proper pressure on the discs—they should hold their settings, yet turn easily. A drop of solder applied to the nut will make the assembly permament. The calculator solves the single phase equation:—

$$\left[\frac{\text{Kva}}{\text{Kv}}\right]^2 \times 2R = W$$

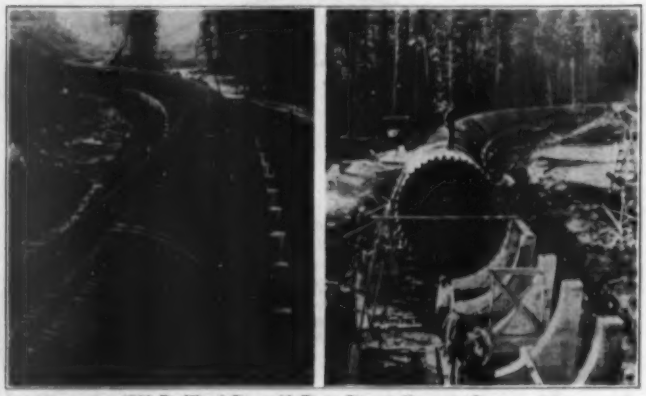
where R is resistance of 1,000 ft. of single conductor and W is watts per 1,000 ft. of circuit. The three phase equation handled by the device is equivalent to the single phase relationship divided by two. Copper conductor is, of course, the basis of design—stranded on sizes No. 2 and larger.

*Now of Public Relations Dept., New York University.


Loss in Watts per 1000 Ft. of Circuit
SINGLE PHASE
LOSS CALCULATOR
How to Use-
Set voltage opposite Kva load and read loss at point opposite wire size
Copyright by V.W.Palen
Wire Size
Voltage
Load in Kva


Loss in Watts per 1000 Ft. of Circuit
THREE PHASE
LOSS CALCULATOR
How to Use-
Set voltage opposite Kva load and read loss at point opposite wire size
Copyright by V.W.Palen
Wire Size
Voltage
Load in Kva.

SPECTACULAR WOOD PIPE INSTALLATION IN OREGON



1780 Ft. Wood Pipe—12 Ft. in Dia. at Yamsey, Oregon

(Installed by Santa Fe Tank & Tower Co. for Toketee Hydro-Electric Plant, this pipe required 300,000 board ft. of lumber and 272,000 lb. of steel bands. All but 370 ft. of the pipe was built on curves.)

San Leandro, Calif. Studies Sewage Effluent Use

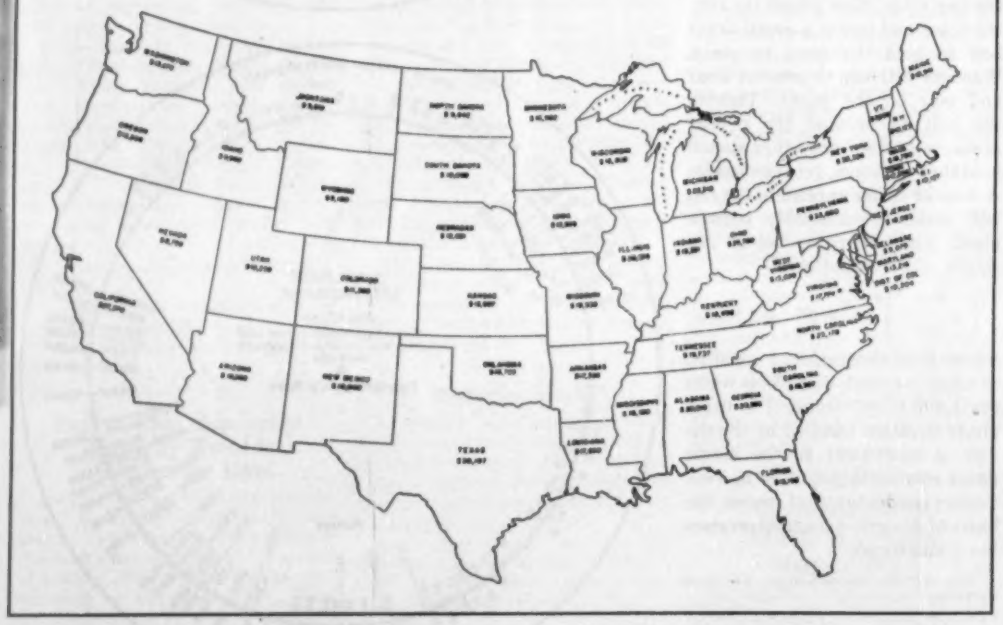
The City Council of San Leandro, Calif., has passed a resolution approving the use of reclaimed sewage treatment effluent for industrial use and has directed the city manager to work with the Chamber of Commerce on further studies.

With a suspended solids content of only 50 ppm. and the possibility of reducing this to 20 ppm., it is believed that reclaimed sewage treatment effluent can be furnished to industrial concerns for approximately $50 per mil. gal., whereas present cost of industrial water for the East Bay Municipal Utility District is approximately $170 per mil. gal.

In these studies, Charles P. Martin, Dir. of San Leandro Pub. Works Dept., and Harvey Wilts, Supt. of Sewage Treatment, represent the city.

U S PHS GRANTS TO STATES AND CITIES

For Industrial Wastes Studies



The accompanying map shows how much each state has received in grants from the Federal Government, through the Public Health Service, under Section 8a, Public Law 845. (The Water Pollution Control Act). These grants are for the purpose of conducting studies of water pollution by industrial wastes. The grants were made for 1950 from a $1,000,000 appropriation for each of five fiscal years, making a total of $5,000,000.

(In addition Alaska received $9,212; Hawaii $9,978; Puerto Rico $9,913; the Virgin Islands $8,645.)

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State Board of Health
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State Dept. of Health
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The Editor's Comments

"The Lengthened Shadow of One Man"

It has been said that—"An institution is often the lengthened shadow of one man."

Of Robert B. Simms, for thirty years superintendent of Water Works at Spartanburg, S.C., it can be said that the Spartanburg Water Works System as it stands today is truly the "lengthened shadow" of this man. However, "Bob" Simms takes credit for his accomplishments in his usual unassuming manner, and impresses upon one that he could have done little but for the confidence and support of those far-sighted Public Works Commissioners of Spartanburg under whom he has served.

Featured in this issue is the story of Spartanburg's Water Works during the past thirty years under the supervision of "Bob" Simms. This month his three decades of notable service is being recognized in the naming of the twice enlarged and modernized filtration plant—*"THE R. B. SIMMS FILTRATION PLANT"*, and the unveiling of a bronze commemorative plaque bearing the citation—*"In recognition of the outstanding vision and service of Superintendent R. B. Simms."*

One has but to read the lead article in this issue to appreciate what a water superintendent with vision, aided by sound engineering and planning on the part of the city's consultants, and the confidence shown in him by his Commission, can accomplish in the way of raising the local water utility to the number one position amongst the public enterprises of his community.

In this accomplishment improved quality and adequacy of water supply in itself was, of course, the basic objective and realization. But along with this has developed the wholesome and rewarding advancement in public relations that has been achieved through the development of publicly acclaimed recreational facilities by the Water Department on water works property. While there may be little that can be glamorized at the householder's faucet, Spartanburg's experience is testimony enough that much can be accomplished in other directions to promote a higher appreciation of water supply service, which is far too prevalently viewed by the public the country over as being just a "matter of course" governmental service.

In addition to the development of the park—playground—pool combination, frequently enjoyed by as many as 5,000 citizens in a single day, who go home realizing that water supply service can be something in addition to the free-flowing tap and fire-fighting pressures, Spartanburg's water authorities did something more. They took the public into their confidence by freely publishing in the local press, and through other means, the physical and the financial condition of the water supply system. Further, after Spartanburg had by successive enlargements of its plant kept ahead with a supply of good quality and ample quantity under adequate pressure, the Commission encouraged unrestricted use of water for home and community beautification through lawn sprinkling. It went a step farther in offering a reduced summer rate on all water used for sprinkling over and above ordinary household uses. At the same time, to industry it offered a reduced off-peak rate to users filling their storage tanks during hours when Spartanburg's mains would otherwise be doing little to produce revenue. This proved a source of added income, while also winning friends amongst the heaviest taxpayers—the industries. With it all, Spartanburg water authorities have never in the three decades of the Simm's regime had to warn of a pending water-scarcity, or hang out the "Please Don't Use" sign.

All of these things and other educational programs designed to improve public relations by showing the public how much its "water dollar" was buying in comparison to other everyday commodities as well as luxuries, have been effective in developing a water conscious public in Spartanburg, ready to support the Commission and Water Superintendent with a degree of confidence rarely enjoyed to the same degree by those in similar positions elsewhere.

The story of Spartanburg's Water Works is an impressive exemplification of the faith of a man in the future of his city, and his ability to secure and hold the confidence and support of his Commission, which support enabled him to get things done which he felt necessary to make the growth and development of his city possible.

It is the writer's pleasure to have devoted this page to what, in part, will constitute his dedicatory address in Spartanburg on May 10th, 1950 at the unveiling of the bronze tablet commemorating the dedication of *"THE R. B. SIMMS FILTRATION PLANT."*

Having served Spartanburg as a predecessor of "Bob" Simms, the invitation and the privilege of making this address is considered a double honor. May there be many another water superintendent who will cast "the long shadow" of this man, and reach the heights that he has in the public esteem.

L. H. Enslow

THE OVERWHELMING MAJORITY *specified* "CHICAGO" SWING DIFFUSERS AND PRECISION TUBES

Sewage Treatment Plant
Columbus, Ohio

Paul A. Uhlmann & Associates
ENGINEERS

THE overwhelming majority of Consulting and Design Engineers who planned equipment for Activated Sludge Sewage Treatment Plants in the past five years specified CHICAGO Swing Diffusers and Precision Diffuser Tubes. It's a question of "Diffused Air Economics". Continuous operation of an Aeration Battery is possible only with Swing Diffusers. The most economical operation is possible with Precision Diffuser Tubes.

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- **Economical operation—less power consumed—less labor.**
- **Tubes easily and economically cleaned.**

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SEWAGE EQUIPMENT DIVISION

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Flush Kleen, Scru-Peller, Plunger, Horizontal and Vertical Non-Clogs Water Seal Pumping Units, Samplers.

Swing Diffusers, Stationary Diffusers, Mechanical Aerators, Combination Aerator-Clarifiers, Comminutors.

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SLUDGE PLANT

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HOFFMAN
CENTRIFUGAL BLOWERS

DEPENDABLE—no gears, valves or similar wearing parts. Operate 24 hours a day, for years without adjustment or replacement of parts.

ECONOMICAL—Power input varies with volume of air required. Retain original efficiency indefinitely—deliver full rated capacity continually.

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For water supply, fire protection systems, sewage disposal systems, industrial, and irrigation. Flexible.

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Gentlemen: Send us information and catalog on UNIVERSAL CAST IRON PIPE.

NAME .....

STREET .....

CITY .....

MEETINGS SCHEDULED:

MAY 3-6—LONG BEACH, CALIF. (Lafayette Hotel)
California Sewage Works Association. Sec'y, Lawrence H. Cook, P. O. Box 696, Menlo Park, Calif.

MAY 10—TACOMA, WASH. (Winthrop Hotel)
Pacific Northwest Sewage Works Association. Sec'y, W. P. Hughes, City Hall, Lewiston, Idaho.

MAY 11-13—TACOMA, WASH. (Winthrop Hotel)
Pacific Northwest Section A.W.W.A. Sec'y, O. P. Newman, Boise Water Corp., Boise, Idaho.

MAY 19—PITTSFIELD, MASS. (Hotel Sheraton)
New England Water Works Association. Sec'y, Jos. C. Knox, 204 Tremont Bldg., Boston, Mass.

MAY 21-26—PHILADELPHIA, PA.
American Water Works Association (Annual convention). Executive-Secretary, Harry E. Jordan, 500 Fifth Ave., New York 18, N. Y.
(Meetings & Exhibits in the Auditorium.) All reservations will be cleared through the A.W.W.A. Headquarters.

MAY 22-24—TRAVERSE CITY, MICH. (Park Place Hotel)
Michigan Sewage Works Association. Sec'y, D. M. Pierce, State Dept. of Health, Lansing 4, Mich.

JUNE 1—WORCESTER, MASS. (Hotel Sheraton)
New England Sewage Works Association. Sec'y, Walter E. Merrill, 511A State House, Boston, Mass.

JUNE 5-10—GAINESVILLE, FLA. (Univ. of Florida)
Florida Annual Water & Sewage Short School. Director, David B. Lee, P. O. Box 210, Jacksonville, Fla.

JUNE 7-9—AUBURN, ALA. (Alabama Polytechnic Institute)
Alabama Water & Sewage Works Association. Sec'y, Alex O. Taylor, Alabama Polytechnic Institute, Auburn, Ala.

JUNE 9-10—INDIANAPOLIS, IND. (Hotel Lincoln)
Central States Sewage Works Association. Sec'y, Paul W. Reed, 1098 W. Michigan St., Indianapolis 7, Ind.

JUNE 12-13—JAMESTOWN, N. Y. (Hotel Jamestown)
New York Sewage and Industrial Wastes Assn. (Spring Meeting) Sec'y, R. C. Sweeney, 119 E. Main St., Rochester, 4, N. Y.

JUNE 14—KITTERY, MAINE
Maine Water Utilities Assn. Sec'y, Earle A. Tarr, Supt. Water District, Winthrop, Me.

JUNE 28-30—CINCINNATI, OHIO (Gibson Hotel)
Ohio Sewage & Industrial Wastes Treatment Conference. Sec'y, G. A. Hall, 302 Dept. of State Bldg., Columbus, Ohio.

JUNE 29—DOVER, N. J. (Germania Park)
New Jersey Section A.W.W.A. (Clambake and Outing) Inspection Trip, Lock Joint Pipe Co., Wharton, N. J. Sec'y, C. B. Tygert, Box 178, Newark, N. J.

AUG. 9—MT. DESERT ISLAND, ME.
Maine Water Utilities Assn. (Summer Meeting) Sec'y, Earle A. Tarr, Supt. Water District, Winthrop, Me.

AUG. 20-22—STATE COLLEGE, PA. (Nittany Lion Inn)
Pennsylvania Water Works Operators Assn. Sec'y, Prof. Robert E. Stiemke, Dept. of Engineering, State College, Pa.

AUG. 23-25—STATE COLLEGE, PA. (Nittany Lion Inn)
Pennsylvania Sewage & Industrial Wastes Assn. Sec'y, B. S. Bush, Penna. Department Health, Kirby Health Center, Wilkes-Barre, Pa.

SEPT. 6-8—ST. PAUL, MINN. (St. Paul Hotel)
Minnesota Section A.W.W.A. Sec'y, R. M. Finch, 518 Metropolitan Life Bldg., Minneapolis, Minn.

SEPT. 7-8—SARANAC LAKE, N. Y. (Saranac Inn)
New York Section A.W.W.A. (Fall Meeting) Sec'y, R. K. Blanchard, 50 West 50th Street, New York, N. Y.

SEPT. 14-15—HUNTINGTON, W. VA. (Hotel Pritchard)
West Virginia Sewage and Industrial Wastes Assn. Sec'y, A. H. Paessler, 815 E. Franklin Street, Richmond 19, Va.

SEPT. 17-21—POLAND SPRING, ME. (Poland Spring House)
New England Water Works Association. (Annual Convention) Sec'y, Joseph C. Knox, 204 Tremont Bldg., Boston, Mass.

SEPT. 19-21—DAVENPORT, IOWA (Hotel Blackhawk)
Iowa Sewage Works Association. Sec'y, Leo Holtkamp, E. Ohio Street, Webster City, Iowa.

MEETINGS SCHEDULED:

SEPT. 20-22—ATLANTA, GA. (Georgia Institute Technology)
Georgia Water and Sewage School. Sec'y, Van P. Enloe, R.F.D. No. 5, Box 363, Atlanta, Ga.
SEPT. 26-29—ATLANTIC CITY, N. J. (Claridge Hotel)
Pennsylvania Water Works Association. Sec'y-Treas., C. M. Hartman, 510 Telegraph Bldg., Harrisburg, Pa.
SEPT. 27-29—SANTA FE, N. MEX. (LaFonda Hotel)
Rocky Mountain Sewage Works Association. Sec'y, C. H. Coberly, Room 329, 1441 Welton St., Denver, Colo.
Rocky Mountain Section A.W.W.A. Sec'y, Geo. J. Turre, Room 120, City-County Bldg., Denver, Colo.
OCT. 1-3—ST. LOUIS, MO. (Sheraton Hotel)
Missouri Water & Sewage Conference. Sec'y, Warren Kramer, State Office Bldg., Jefferson City, Mo.

OCT. 9-12—WASHINGTON, D.C. (Statler Hotel)
Federation of Sewage Works Associations. Exec.-Sec'y, W. H. Wisely, 325 Illinois Bldg., Champaign, Ill.

OCT. 11—WATERVILLE, ME.
Maine Water Utilities Assn. (Marks the 25th Anniversary of founding of the Ass'n.) Sec'y, Earle A. Tarr, Supt. Water District, Winthrop, Me.
OCT. 15-18—NEW YORK CITY, N.Y.
American Public Works Association Congress. Exec.-Director, Donald Herrick, 1313 East 60th St., Chicago 37, Ill.
OCT. 15-18—NEW ORLEANS, LA. (Roosevelt Hotel)
Southwest Section A.W.W.A. Sec'y, Leslie A. Jackson, Robinson Memorial Auditorium, Little Rock, Ark.
OCT. 24-27—SAN DIEGO, CALIF.
California Section A.W.W.A. (Annual Meeting) Sec'y, Wm. W. Aultman, Box 38, LaVerne, Calif.
OCT. 26-27—DETROIT, MICH. (Detroit Leland Hotel)
Michigan Section A.W.W.A. Sec'y, T. L. Vander Velde, 2609 E. Saginaw St., Lansing 12, Mich.

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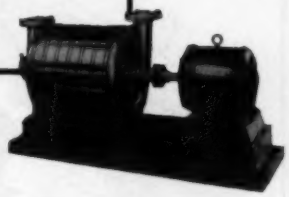
MULTI-STAGE BILLMYRE TYPE BLOWER



Centrifugal type
Single and multi-stage
½ lb. to 7 lbs. pressure
½ hp. to 250 hp.

Since back in the '90's, these trustworthy Blowers and Exhausters have been faithfully serving American industry—for agitation and aeration—for combustion—for cooling and ventilating—for gas and acid production—for conveying—and numerous other applications having various pressure and vacuum requirements.

If you have a problem in handling air or gases of various densities, temperatures or chemical compositions, write today for latest bulletin, B-5, on Lamson Blowers and Exhausters.

LAMSON Corp. BLOWER DIVISION
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CARTER CIRCULAR COLLECTORS

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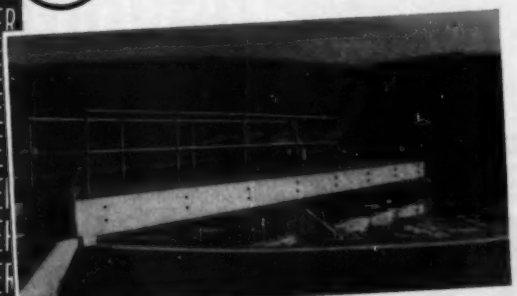

- **For primary clarification of raw sewage, waste or turbid waters**
- **For final clarification of activated sludge**
- **For clarification of chemically treated water**
- **For water softening**

Type S Primary Clarifier at Ft. Payne, Ala. 42'0" dia. x 8'0" SWD. General Contractors: J. E. Wooley Co., Birmingham, Ala. Consulting Engineers: J. W. Goodwin Eng. Co., Inc., Birmingham, Ala.

The Carter "Type S" Circular Collector is designed for tanks of 10' to 50' in diameter, with side influent. Standard construction includes mechanical electrical overload protection; vertical speed reducer combination type drive; automatic continuous surface skimming—for primary tanks. Flow blade scrapers provides positive, continuous spiral flow of settled solids from tank bottom periphery to central hopper—guaranteeing a thickened sludge. This improved clarification mechanism eliminates both septic conditions and excessive surface scum formations.

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Our Bulletin No. 4906 gives you complete engineering data and specifications on all 3 types of Carter Circular Collectors. Write for it today.

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Look at *R-C dual-ability* with its wide selection to suit almost any job

Asking Roots-Connersville about blowers, exhausters and gas pumps has been standard practice among buyers for almost a century. That's because building such equipment is the only job we do. We're outstanding specialists in handling gas and air.

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So—when shopping, be sure to call on Roots-Connersville, the specialists. When you're interested in vacuum pumps, meters or inert gas generators, we're equally well fitted to fill these needs, too.

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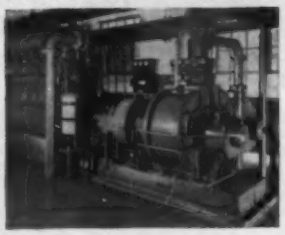
505 Mount Avenue, Connersville, Indiana

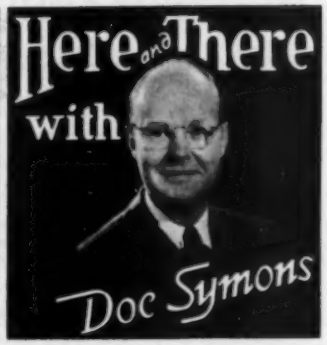
Installation of 2-stage Centrifugal Blower in southern sewage treatment plant. Capacity 13,500 cfm.

One of two Rotary Positive Blowers, engine driven, in small sewage treatment plant. Capacity of each, 4,750 cfm.

ROTARY



ROOTS-CONNERSVILLE
ONE OF THE DRESSER INDUSTRIES



H.T.M.A.—And here's that Reference and Data issue again—Need I say more?—

* * *

Well what d'you know—Just a week after I wrote about Art Morrill in China I received a letter from Jim Potter of Charlotte, N.C., mentioning Art. Jim is the fellow who had those clever cards which he sent to all my friends requesting same. In return for the cards, Jim asked for a postcard for his daughter. Art Morrill requested Jim's cards, received same and sent a postcard (arriving March 8th) on which was written, "It's a long time since I received your Dad's letter of April 4, 1949, but we have been making history in China in the meantime. I got it May 18, just a week before the Communist Army took Shanghai, without much fighting. Scenes like this are common in China, picturesque, but a little smelly"—the scene is a house-lined canal in a village; a man is poling a flat-bottomed boat; in the foreground is an arching bridge; the two and three-storied houses exhibit washing hung out to dry.—Art wrote something in Chinese on the card but Jim hasn't yet seen his laundryman for a translation.

* * *

The Correct Solution For Floods—Where Wendell (Akron, Ohio) got it, I have no idea, but he has "The Correct Solution For Floods" as proposed in a circular by a fellow in Illinois. In brief the "inventor" proposes that electrically operated propellers be placed in every river and its tributaries; large propellers in big streams and small ones in little streams. "A few propellers strung across the channel will be sufficient. They can be attached to piers or partly suspended from bridges." The idea is that when it rains, you turn on all the relays of propellers distributed quite a long distance apart and the water will be "pushed"

(*Continued on page* 120A)

removed under pressure

This pipe section was cut, under pressure, from a 48" main without shut-down or other interruption to service. The operation was performed in the course of inserting a gate valve in a 48" cast iron main, in the distribution system of the Water Bureau, City of Philadelphia, Pa.

Gate valves can be inserted under *pressure* by SMITH in cast iron, asbestos–cement or steel water mains, sizes 4" and larger, without shutting off service or dewatering the line.

30

GATE VALVES
CHECK VALVES
FIRE HYDRANTS
INSERTING VALVES
TAPPING SLEEVES AND VALVES
WATER SERVICE BRASS GOODS

THE A. P. SMITH MFG. CO.
ESTABLISHED 1896
EAST ORANGE, NEW JERSEY

FLOOR STANDS
INDICATOR POSTS
TAPPING MACHINES
INSERTING MACHINES
PIPE CUTTING MACHINES
CORPORATION TAPPING MACHINES

(*Continued from page* 118A)
rapidly downstream and there will be no flood.

Perhaps Wendell LaDue will explain more about this new invention at the annual breakfast of the Society of the Council Bluffers to be held after the A.W.W.A. dance in Philadelphia on Thursday, May 25.—

* * *

Here is a letter I received some time ago from A. M. Rawn, Gen. Mgr. and Chief Engr. of the Los Angeles County Sanitation District. —This is really good—

The following rules of conduct and procedure for a sewage treatment plant operator are the result of many years observation on my part. I have entitled these rules, "Pardon Me, But Your Pink Slip Will Soon Be Showing" or, "Don't Be An Old-Fashioned Plant Operator." (If any of the men who work for me chance to read this, they will realize that I couldn't possibly have formulated these regulations because of my experience with them. They all know the "Old Man" is quite a kidder).

Rule No. 1: As a plant operator, bear in mind always that you are in complete control of all of the "bugs." Don't stand for any nonsense from them.

Rule No. 2: Remote electrical control gadgets are put around just to confuse you. If they're in the way and you don't understand what they mean, give them the well known business and forget them.

Rule No. 3: Don't pay any attention to the plant chemist or any chemist, for that matter. Chemists are queer people who are put in the plant to annoy you. They're supposed to be very bright but if they're so damn smart, let them guess what you're doing.

Rule No. 4: Don't hesitate to jerk the hell out of anything that sticks. If it won't come that way, use a spanner or a double jack.

Rule No. 5: If the plant designer failed to anticipate every contingency at your plant and to design accordingly, make him live to regret it. He's probably just another one of those lousy college bums anyway.

Rule No. 6: Never close the gate behind the switchboard. Some careless visitor may need the opening to fall out of some day.

---

*Editorial Associate, *Water & Sewage Works.*

Rule No. 7: Treat all visitors as though the plant belonged to you. Impress them with what a big shot you are and how little they know. If possible, create the impression that the city health officer takes his orders from you.

Rule No. 8: Don't pay any attention to odors. After all, you're just a branch of the city hall. Those whom you facetiously refer to as the "city hall gang" will appreciate the joke, if you refer to both departments as being a "little smelly."

Rule No. 9: Don't read *Sewage Works Journal* or *Water & Sewage Works* under any circumstances. Out of five thousand members of the Federated Sewage Works Associations you are probably "tops". Anyway, what's Mohlman got that you haven't?

Rule No. 10: Lastly, if you're going to be this kind of an operator, just one more thing:—Don't apply first aid to cuts and scratches. They don't amount to much . . . . very many times . . . . and you may be one of the lucky ones . . . or the city may. Quien sabe? "A.M."

* * *

Modern Generation—Many of you who know our son Jimmy know that he is now studying Civil Engineering at Cornell. One of his surveyirg problems called for building a railroad and balancing the cut and fill. Object was to cut no more than was needed for fill.—An excess meant expense of moving the dirt.—Jim came out with a few hundred cu. yds. extra cut and suggested to Prof. Spry that he would sell the extra

Count on SOLVAY CHEMICALS

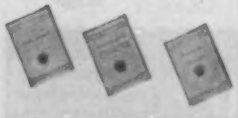
FOR TREATMENT OF SEWAGE AND INDUSTRIAL WASTES

Based on past performance . . . you can count on SOLVAY Liquid Chlorine, Soda Ash and Calcium Chloride to give highly satisfactory results in treating sewage and industrial wastes.

You can also count on SOLVAY for prompt delivery of these important chemicals from centrally located plants and a coast-to-coast chain of warehouses. SOLVAY Technical Service is also available—to give you technical and engineering information; to help solve your problems in the treatment of sewage and industrial wastes.

These SOLVAY Technical and Engineering Bulletins Are Available Without Cost or Obligation. Ask for Any One or All Three . . . Write Today.

Bulletin No. 7—"Liquid Chlorine"
Bulletin No. 8—"Alkalies and Chlorine in the Treatment of Municipal and Industrial Wastes"
Bulletin No. 11—"Water Analysis"



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earth for top soil at New York prices —a buck a bushel.—Hmmm—

* * *

Harry Faber to the contrary—Here's another pair of hands. They've been doing a lot of work in water supply and sewage disposal for a long time.

If you don't recognize them now, you will—Know who it is?—One year subscription to first five correct replies.

* * *

My Elizabeth, N.J., correspondent crashed through with the answer to the water shortage. Yep—Sam (II) Newkirk sends the following clipping showing that "Abortwasser—Spargerate" is the answer.

The inventor is Gustav Freitag of Butzvach-Hessen, Germany, who wrote "By means of my invention, the house owner has to pay 2/5 of 54,000 liters, or 21,600 liters per year. On both counts, you can see that the house owner only has to pay for 21,500 liters per year, while under the old system 54,000 and second 5 c.b.m. against 54 c.b.m. So the home owner saves 54-21 c.b.m. or 33.4 c.b.m. and the water works saves 54 c.b.m."

And there you have it.—

* * *

Not a few of you know that I like poetry and am very interested in Shakespeare's work. Unlike many Shakespearing devotees, I enjoy a good parody even of Hamlet's famous soliloquy, and here's a good one I think—with apologies to Shakespeare.

A Sludge Soliloquy

Inspired by Meditations of Mudgett, Marquis of Muskegon

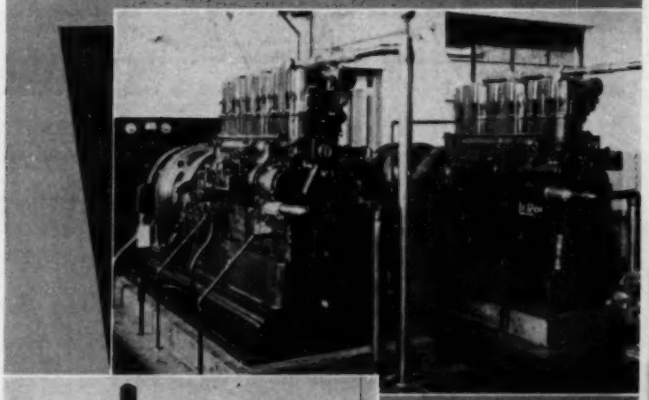
Scene I: *Muskegon Sewage Treatment Works. Mudgett at his post. Gazes anxiously toward settling tanks and digesters. Speaks softly:*

Mudgett:

"To pump, or not to pump: that is the question.
Whether 'tis best deep in the murky depths of hoppers
There to lie, well buried, the noisome sight

LE ROI MILWAUKEE

Saves 6 times initial cost in 12 years of continuous service!



Modern sewage disposal plant at Oshkosh, Wisconsin and its 2 LeRoi 6 cylinder engines, direct-connected to 50 KW, 3 phase 60 cycle, 440 volt, induction generators.

Here's proof that Le Roi Engine Generator Sets save taxpayers' money!

In Oshkosh, Wisconsin, two Le Roi engine-generator units operating on "no-cost" sewage gas produce electric power at a cost of .398¢ per kwh. This extremely low cost includes charges for labor, insurance, depreciation, and repairs. Purchased power at the utility rate would be 1.507 cents per kwh. Using Le Roi results in actual savings of nearly $4000 a year for taxpayers!

Lubricating oil, repair parts, and labor cost less than $600 a year for these two twelve-year-old engines. This is real evidence of Le Roi long-life and dependability.

Le Roi engines are available in sizes ranging from 6 to 600 hp — custom generator sets in sizes from 30 to 300 KW. They operate on no-cost sewage gas, natural gas, butane, or gasoline. Lighten the tax load in your community. Investigate the advantages of Le Roi low-cost power. Send the coupon below for a detailed report of this and other money-saving installations.

LE ROI COMPANY

Milwaukee 14, Wisconsin

New York • Washington • Cleveland • Birmingham
Milwaukee • Tulsa • Dallas • San Francisco

Tear out this coupon and mail TODAY!

LE ROI COMPANY MILWAUKEE 14, WISCONSIN

Please send me complete information on the Oshkosh, Wisconsin Le Roi Engine installation plus other cost-cutting job reports.

Name.....

Title.....

Address.....

City.....(...) State.....

8-47

Escaping human eye and consciousness
Till, warmed by summer's breath and in the flight of time,
It comes alive; and from the yawning maw of monster vile
Regurgitates a boiling, belching mass in ever widening rings
Of filth and so defile the effluent? Or pump instead,
And impress indeed, more load, more misery
Upon a unit bulging now in every seam;
Strained with overload of sludge, alive with reeking gas,
In nature's sweet and open air to seek relief.
To pump indeed, and yet again; and with
The chill of excess cold from liquid volumes unrestrained
Strike deep into the heart and life enclosed within those walls
Till life itself expires. Aye, pump indeed,
And pay the penalty of overload; a frothing, seething
Monster unrestrained, unformed, a creeping, flowing
Mass of viscous ooze invading every nook;
A foul and endless sea submerging all.
Or yet again, perchance in secret and in stealth,
Abetted by pale ghostly light of silver moon
Provide relief to yonder swale or shimmering stream
As heathen kin of western lands confess to do
Accursed indeed am I upon whom such decision rests;
And for him, hate eternal I shall bear and nurse
Within my breast, from whom upon me came this woe:
An undersized digester."

(The above item appeared in the Michigan Sewage Works Bulletin, edited by W. F. Shepherd, Mich. Dept. Health, Lansing, Mich. —Mudgett is C. T. Mudgett, Supt., Sew. Treat. Wks., Muskegon, Mich.)

* * *

My apologies to the boys at the N.J. Sewage Works Assn. meeting in Trenton in March. Sorry I couldn't stay, fellows, but a severe case of gastronenteritis sent me packing and home to my blonde nurse, my bed, and my sulfa capsules. Understand that I missed another good show at your famous speechless dinner.

* * *

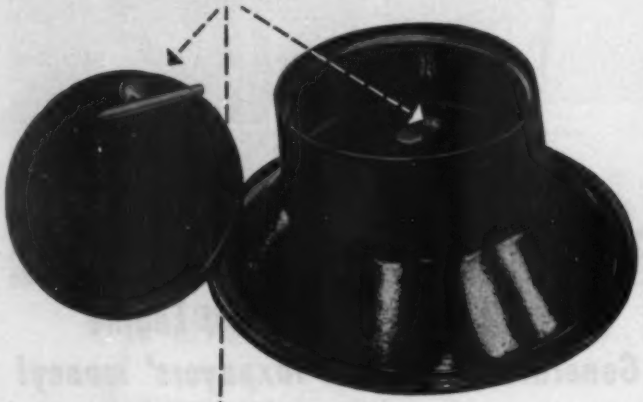
The voting is divided: Fred W. Deutsch (Sales Manager of Builders' Standard & Engineered Prod. Div.) and his wife disagree on Shrimp Shorb. He liked it, she didn't—Well anyway I'm glad to know that someone tried it. Incidentally, Fred has just been elected to the Board of Directors of The National District Heating Association.

* * *

That'll be all for the moment but see this space next month for a Special Announcement.

V.T.Y.—Doc.

WABASH DOUBLE-LID COVERS



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The Wabash Cover was designed to provide the utmost in frost protection for pit water meters. Two lids, with a 4" dead air space between, add extra insulation. Notice also, the extra depth and the sloping skirt that help hold heat loss to a minimum.

Top lid is inset and locked with the patented Ford Lifter Worm Lock. There is no finer meter setting protection.

FOR BETTER WATER SERVICES — FORD

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Wabash, Indiana

[Overflow from the main section]

A Most Unusual Water Supply

One of the most unusual waters in the nation is that of the public water supply of Pensacola, Fla., which is derived from wells approximately 190 feet deep which yield a water averaging only 12 p.p.m. hardness. Aeration and lime treatment for stabilization and corrosion control plus chlorination constitutes the only treatment given the water. What catalogs the Pensacola water as unusual is the fact that an application of only 0.05 p.p.m. of chlorine yields a residual of 0.05 p.p.m. (that's right, 0.05 p.p.m. residual from 0.05 p.p.m. added) and this quantity of residual chlorine remains throughout the entire distribution system. Effective disinfection results. It is obvious that the chlorine demand of the

(*Continued on page* 124A)

It takes a TAPERED PLUG

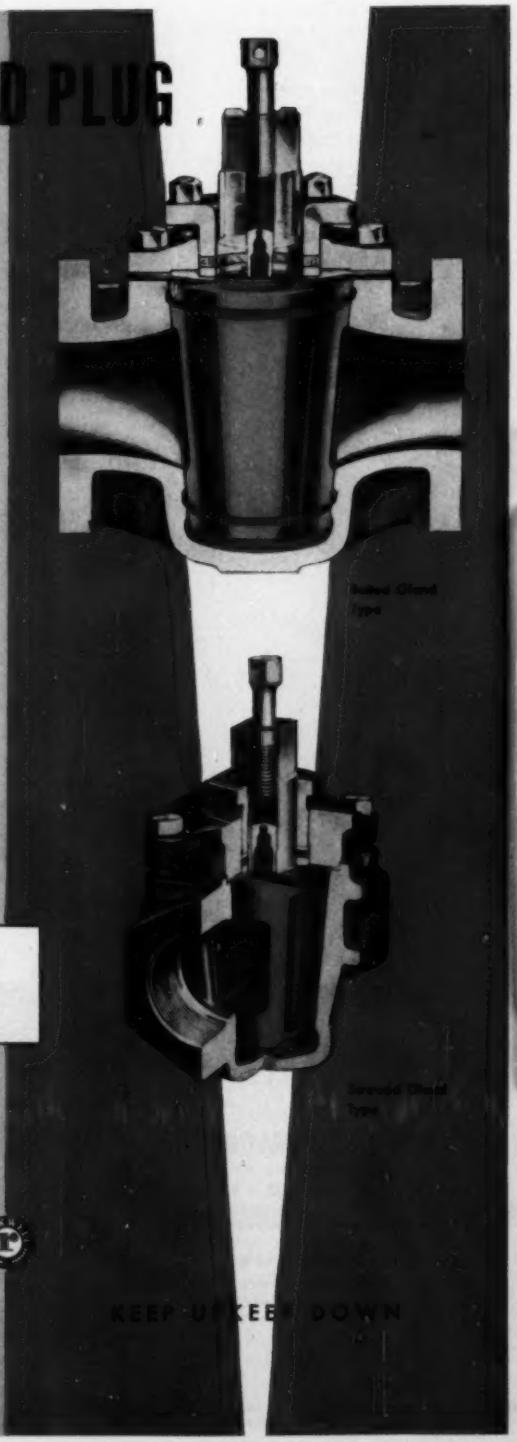
to successfully handle Sewage Sludge

TAPERED PLUG PREVENTS SEAT SEPARATION IN NORDSTROM VALVES

▼ An exposed valve seat is subject to rapid wear. Grit grinds out the seat. Note how Nordstrom valves give full protection to the seat. Being tapered, the plug is always positively seated on a film of protective lubricant. A quarter turn fully closes or opens the valve. The plug can be jacked if ever too tight by turning the lubricant screw.

Kept sealed, automatically

"Sealdport" lubrication forms an effective leak-resistant seal around each port. Use of Rockwell Hypermatic lubricant *automatically* lubricates the valve, maintaining constant pressure within the valve so that frequent re-lubrication is unnecessary. Specify Nordstrom valves on all sludge lines, gas, air and water lines.



Grit cannot intrude. Plug seats on lubricant
"Sealdport" lubrication seals ports
Hypermatic automatically lubricates

Nordstrom Valves

Nordstrom Valve Division
ROCKWELL MANUFACTURING CO.
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Atlanta, Boston, Chicago, Columbus, Houston, Kansas City, Los Angeles, New York, Pittsburgh, San Francisco, Seattle, Tulsa.
Also leading supply houses
Export: Rockwell Manufacturing Co., International Division, 2701 Empire State Building, New York 1, N.Y.

KEEP UPKEEP DOWN

(*Continued from page 122A*)
Pensacola well water is so low as not to be measurable.

Principles and Practice of Flow Meter Engineering

"Principles and Practice of Flow Meter Engineering" by L. K. Spink has been published by the Foxboro Co., Foxboro, Mass. This is the seventh edition since the book was first published in 1930 and this edition contains new and up-to-date material. In this edition, a new section has been contributed by R. L. Parshall, inventor of the Parshall Flume.

This handbook contains all of the necessary information for calculating an orifice, flow nozzle, Venturi tube, Pitot tube, or even a pipe elbow used for flow measurement. Pressure tap locations, liquids, steam and other vapors, as well as gas are handled in separate sections. Instructions, curves, and tables are presented in logical sequence along with viscosity corrections, equations and curves for calculating throttling orifices.

New features include a complete section on measurements of fluid flow in metric units, barometic pressure correction table, and several other tables and charts.

"Principles and Practice of Flow Meter Engineering" contains 416 pages of text and illustrations and may be obtained from the Foxboro Co., Foxboro, Mass., for $7.00 a copy.

Kinks To Prevent Wire Rope Kinks*

Do you use wire rope? Ever have trouble with kinks? If so, these illustrations will be of value to you, or, if you are a prospective user they show what to guard against.

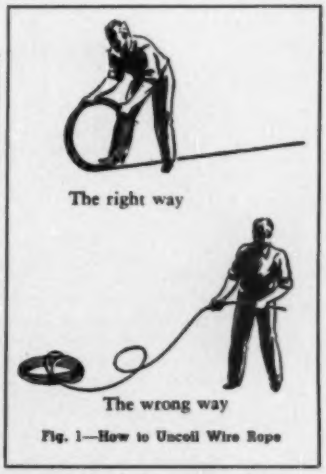

Fig. 1—How to Uncoil Wire Rope

To obtain maximum service from wire rope careful attention should always be given to methods of handling as indicated in these drawings. Fig. 1 shows how to uncoil wire rope. Fig. 2

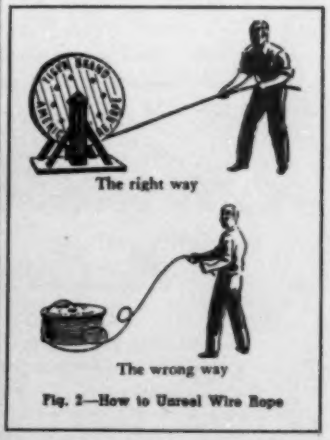

Fig. 2—How to Unreel Wire Rope

*Contributed by W. F. Schaphorst, M.E., Newark, N.J.

(*Continued on page 126A*)

▶ PIPE LINING FACTS NO. 1 ◀

▶▶▶ CENTRILINE restores the original carrying capacity of old water mains at reasonable cost by the centrifugal application of a cement lining. This smooth, dense, continuous coating defies corrosion and tuberculation. Hence, carrying capacity is sustained for the lifetime of the main.

The ever-smooth, protective lining centrifugally applied by Centriline in some instances has increased carrying capacity beyond the rate of the pipeline when originally installed. This is due to the homogeneity of the lining which covers seams, joints and rivet heads.

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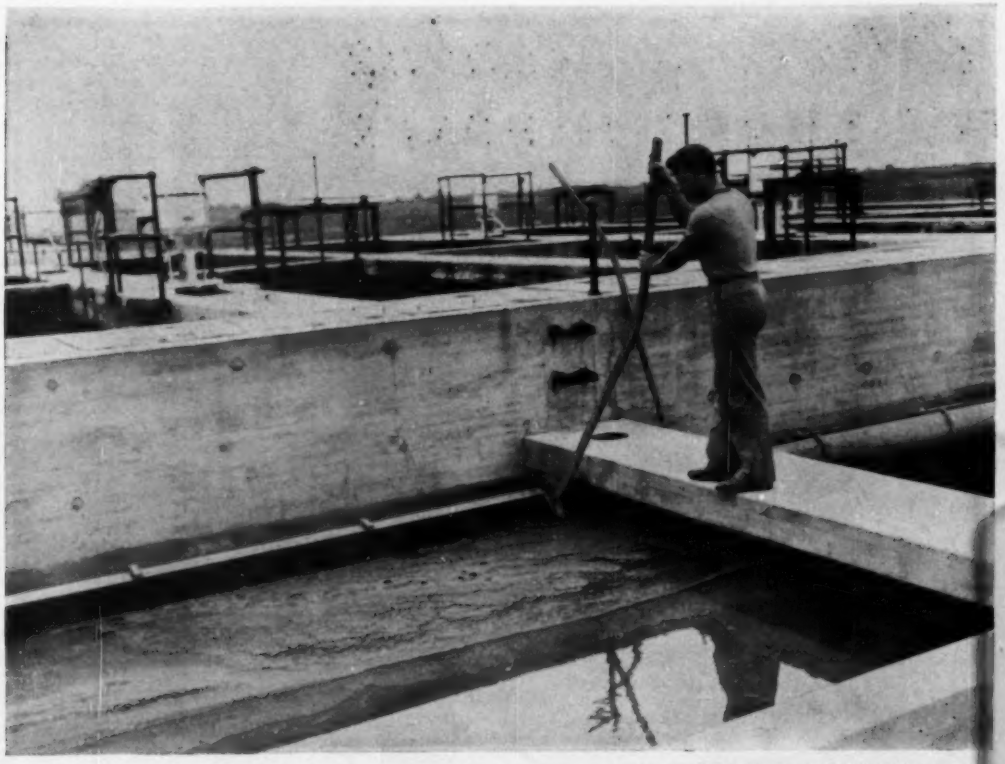

Scum collectors installed in 1934 at treatment plant of the City of Rochelle, Illinois.

SIXTEEN-YEAR UPKEEP: ZERO

Read what the City of Rochelle, Illinois says about scum collectors of Alcoa Aluminum installed in their municipal sewage disposal plant . . .

"The scum troughs were put into operation about 1934 and are still giving satisfactory service . . . *cost of maintaining same has been practically nothing.*"

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Free Patented Carrier for any set

RIDGID

WORK-SAVER PIPE TOOLS

THE RIDGE TOOL CO. • ELYRIA, OHIO

(*Continued from page 124A*)

shows how to unreel. Fig. 3 shows how a kink starts, how the rope kinks, and how it looks after straightening. After straightening the wires may or may not be broken—but the damage is done. The rope has been weakened, and when put to work the wires will soon break. Never use a wire rope that has been kinked unless you completely cut out the kinked portion.

Fig. 3—A Kink and Effects

The writer is indebted to the Columbia Steel Co., Subsidiary of the U. S. Steel Corp., for permission to reproduce these valuable illustrations.

Ohio Compact Commission to Hold Industrial Conferences

The Ohio River Compact Commission will hold group conferences for representatives of industries located in the Ohio River Basin. The dates for the meetings have not been set but more than a year has elapsed since all industries in the Ohio Valley were advised of the interstate compact and the effort to abate pollution.

The Commission now desires to learn what industry has done in the interim and to clarify any misunderstandings regarding industry's responsibilities in the 8-state campaign for stream cleanup.

Hydraulic Diagram No. 2

Some time ago, *The Contractors record and Municipal Engineering* of London, Eng., published the first in a series of Hydraulic Diagrams prepared by L. B. Escritt. Now the second in this series has been published. This one is titled "Flow in Pipes,

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WATER & SEWAGE WORKS

Will see that you receive information desired.

Culverts, Channels, and Streams—Flow in New C.I. Mains—Flow over Broad Crested Weirs."

These three diagrams are printed on heavy serviceable paper and are folded to a pocket size of 5 x 7½ inches, with two heavy cardboard covers attached. The whole opens up to a 15 x 20 inch size. Two of the diagrams are 8½ x 11 inches and the third is 8½ by 14 inches. These are handy diagrams for the designing engineer.

The price is 4 shillings for a single copy or 3 shillings six pence for more than six copies. These diagrams may be obtained from The Contractors Record and Municipal Engineering, Lennox House, Norfolk Street, London, W.C.2.

Valuable Painting Kinks?*

One of the best painting kinks this writer has ever known was told to him by an experienced painter a short time ago—a kink that is surely of sufficient value to be chronicled in print. The painting expert said, "When you go up a ladder with a bucket of paint it is usually best to have only a small amount of paint in the bucket. Don't go up with a full bucket." Then the painter went on and gave his reasons, which the writer jotted down as follows:

1—If you should happen to drop the bucket and the paint spills out, you won't lose much paint and the possibility of damage to property will be less;

2—You needn't be as careful in handling the paint as you must be if the bucket is full, hence you can work faster;

3—If you must use your hands for some other purpose and must let go of the brush temporarily you can place it upright inside the bucket, whence it cannot fall out; and, most important of all—

4—When dipping your brush you are not obligated to "look" for fear of dipping too deep or not deep enough—you know by the "feel" that when the brush touches bottom you have the desired amount of paint on it.

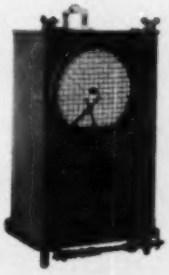
Point 4 is particularly valuable when you are in a "tight place" as one sometimes is when on a ladder and it is difficult or even impossible to look downward. This therefore is a safety measure as well as a time-saving kink.

Another of this expert's pet kinks is to mix paint with putty when puttying the windows. He uses paint of the same color as used on the building or

*Contributed by W. F. Schaphorst, M. E., Newark, N.J.

HOW TO CHECK WATER WASTE AND LEAKAGE

with Simplex Pitot Equipment



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PF PITOT ROD

Here is an easy solution to the problems of harassed municipal engineers who are constantly seeking ways of detecting leaking pipe joints or pipe breaks . . . to conserve precious water supplies and prevent wastes. The Simplex pitot rod, manometer, and recorder form an unbeatable team for checking water wastes and measurement of flow through pipe lines in inaccessible places or where permanent measuring equipment is not installed.

Each unit is completely portable, light in weight, rugged in construction and designed to withstand the hard treatment of being moved from station to station. By using this equipment, complete and accurate flow records through branches or trunk mains are obtainable with minimum effort.

Write for free Bulletin #50 describing this equipment, to Simplex Valve & Meter Company, Dept. 5, 6743 Upland Street, Philadelphia 42, Pa.

SIMPLEX

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windows so that it will not be necessary to paint the putty after it is in place, which is always a rather difficult and time-consuming task. In fact, putty is too often permitted to retain its own natural gray color during its whole life despite its disagreement with the color harmony of the remainder of the building.

This expert has also found that he can make the putty stick better by first cleaning the window frames and adding a coat of paint before using his paint-mixed putty. Allow the paint to become almost dry and then apply the putty-paint combination. The putty will then adhere very well—much better than without the initial coat of paint.

And finally, this expert has learned that the putty will stick better if the window pane is given ample clearance all around so that a "crack" will exist between the edge of the glass and the wood into which putty can be packed. In other words, don't make a tight fit when you put in a window pane; a "loose" fit is better if putty is to be used, and the reason why is logical and obvious in view of the above.

Lime Handling, Application and Storage

The National Lime Association has recently published a 71-page book on **Lime Handling, Application and Storage in Treatment Processes.**

This book, authored by Dr. Willem Rudolfs, Head, Dept. of Sanitation, Rutgers University, will be found helpful to engineers interested in the design, equipment, and operation of municipal and industrial water treatment plants, sewage and industrial waste treatment plants, and chemical processes where lime is used.

This bulletin contains data on the principal methods and types of feeders, slakers, hoppers, solution pots, and discusses the advantages and disadvantages for each type of equipment.

Copies may be purchased at 50 cents each plus postage by writing directly to the National Lime Association, 927 Fifteenth St., N.W., Washington 5, D. C.

Household Sewage Disposal Studies

The U.S. Public Health Service has issued Part I of "Studies on Household Sewage Disposal Systems." This is the first report on the sponsored research project which has been conducted at the Environmental Health Center in Cincinnati, Ohio since Nov. 1946, under the joint sponsorship of the National Housing Agency (now the Housing and Home Finance Agency) and the Public Health Service.

This Part I reports progress on seven of the project objectives. These include: Review of Literature; Controls and Practices in Local Health Units; Experimental Study—Septic Tanks; Field Study—Scum and Sludge Accumulations; Sludge, Yeast as Starters; and Zeolite Softener Salts and Digestion.

This report begins a series to be released from time to time as the work progresses toward the development of scientific data which will form the basis of adequate design and performance standards. Current research includes the continuation of study of septic factors and a start on the investigation of soil clogging and absorption field characteristics.

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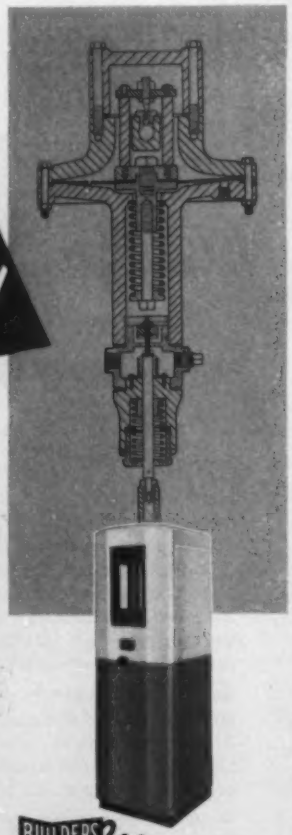
Control . . . of paramount importance in chlorine gas feeding . . . is a major feature of Builders Chlorinizers. With their unique diaphragm control valves, these feeders keep chlorine gas flowing evenly, accurately. Automatic compensation is built in . . . temperature and pressure changes have no effect on the accuracy of chlorine delivery. Here's the valve that brings true watchdog dependability to the chlorination of water and sewage.

For extra safety, the Chlorinizer control valve incorporates a powerful coiled spring, poised, ready to cut the chlorine flow if any condition occurs to interfere with safe operation. Learn more about the many advantages of Builders Chlorinizers: for manual, semi-automatic, program, or flow-proportional chlorination. For Bulletins and engineering information, address Builders-Providence, Inc. (Division of Builders Iron Foundry), 350 Harris Ave., Prov. 1, R. I.



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A limited number of copies of this report are available for distribution on request to the Public Health Service, Environmental Health Center, Cincinnati, Ohio. Additional copies of the report may be obtained from the U.S. Governmental Printing Office, Washington 25, D.C. at $1.25 each.

Inverted Tin Can Makes String Receptacle*

An inverted tin can serves very well to keep a ball of string from wandering all over the place.

Punch a hole in the bottom of the can, as indicated in the accompanying sketch, run the string through the hole, put the ball of string in the can, put on the cover, and there it is.

Invert the can instead of putting the hole through the top because the weight of the can is sufficient to keep it intact. When the cover is used as the top and the hole punched through the cover it may come off when pulling the string out due to the lightness of the cover.

If desired, of course, the cover can be tacked in place on a table or elsewhere, making it a permanent fixture.

Blast Furnace Slag

The Bureau of Mines, U. S. Dept. of the Interior, has issued a bulletin on "Iron Blast Furnace Slag—Production, Processing, Properties, and Uses." Publication of this book, which is designed primarily as a useful reference on the subject of blast furnace slag, was made possible by the coordinated efforts of the Bureau of Mines and the National Slag Association. Copies of this bulletin may be obtained from the National Slag Assn., 644 Warner Bldg., Washington 4, D.C.

*Contributed by W. F. Schaphorst, M. E., Newark, N.J.

Establishing remarkable records for high purification at low cost—

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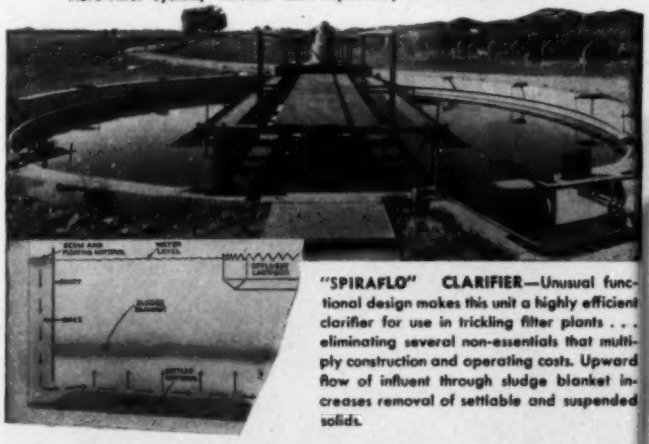
SINGLY . . . OR IN COMBINATION

. . . especially in the treatment of strong industrial wastes

Low construction cost . . . low operating cost . . . high purifying efficiency: these are the characteristics of the Yeomans "Spiraflo" Clarifier and the "Aero-Filter System," whether used separately or in combination.



"SPIRAFLO" CLARIFIER—Unusual functional design makes this unit a highly efficient clarifier for use in trickling filter plants . . . eliminating several non-essentials that multiply construction and operating costs. Upward flow of influent through sludge blanket increases removal of settlable and suspended solids.

"AERO-FILTER SYSTEM"—Simplified design of this high capacity biological trickling filter cuts construction costs—reduces size of required filter bed by about 85%. High efficiency of single stage operation eliminates need of installing and operating expensive conventional recirculating equipment.

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IMPORTANT INFORMATION—Facts as to remarkable records established by Yeomans units will be helpful in your project planning. Bulletins containing performance data, field engineering data and construction cost estimates are available on request—use the coupon.

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Hydroelectric Handbook

"Hydroelectric Handbook" by William P. Creager and the late Joel D. Justin has been completely revised and reissued. Out of print since 1939, this widely used reference has been expanded and brought up to date.

Forty-four authoritative chapters include such topics as power costs, hydraulics, estimating stream flow, powerhouses, conduits, turbines, and generator installations. The new edition provides engineers with current and practical data on the design and construction of all types of hydroelectric plants, dams, and irrigation projects. Contributing to this edition are eighteen other authors on various phases of hydraulic engineering.

The new Creager-Justin handbook contains 1151 pages and features 600 illustrations. The Hydroelectric Handbook is published by John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N.Y. and retails for $12.50 a copy.

Determination of Dissolved Oxygen

Issued as one of the Standards of the Heat Exchange Institute, the "Method and Procedure for the Determination of Dissolved Oxygen" is now available in its first edition. This 32-page book presents the test method as developed by the Heat Exchange Institute. This test is in substantial agreement with the ASTM D-888; differences are limited to the prescribed test apparatus, some phases of the test procedure, and to the recommended scope of usage.

The book contains eleven sections devoted to reagents, calibration of reagents, equipment, sampling, titration, computations, interference, and accuracy, precision and interpretation.

One of eight standards issued by the Heat Exchange Institute of 90 Church St., New York 6, N.Y., this book may be obtained for $2.00 a copy.

DIESEL POWERED MUNICIPAL PUMPING STATION REPORTS PUMPING COSTS CUT 25%

Three New Pumps Replace One Old

The age of the damaged pump and high cost of repairs militated against any attempts to put it back in operation, and thus the decision was made to replace it with the three horizontal centrifugal pumps. The pumps selected were Peerless Pumps, characterized by the occurrence of normal operation in the 87% efficiency range. Normal operation, dictated by the top level of elevated storage, is at 67 pounds' pressure and 2,500 gpm.

Reprinted from American City Magazine, February, 1950

87% EFFICIENCY RANGE CHARACTERIZES PEERLESS PUMP INSTALLATION FOR EASTERN CITY

Municipalities count high efficiencies over extended pumping periods as only one reason for their acceptance of Peerless centrifugal pumps. Dependability, ease of maintenance, widest capacity range, quality construction set the Peerless standard for pump performance and operating economy. Look to Peerless for continued leadership in pumping water at measurable savings. Write today for Bulletin B-1300 describing and illustrating Peerless Type A horizontal pumps, shown installed in the photo above.

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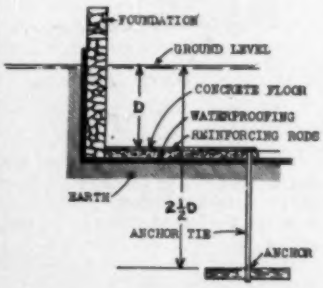
A Basement Waterproofing Kink*

It is not difficult to waterproof a cellar or basement despite the common contrary belief. The principal essentials are: 1—Know how to do it; and, 2—Do it carefully.



The accompanying sketch shows a method developed by this writer for reducing the floor thickness to a minimum and yet have perfect waterproofness by using an anchor at the correct depth beneath the floor level. Thus for example if the depth D of the floor is 4 ft. beneath the ground level, the anchor should be placed 10 ft. beneath the ground level. Simply multiply the depth of the cellar floor beneath the ground level by 2½ and you have the depth of the anchor beneath the ground level.

As indicated, the proper place for the reinforcing rods is near the "top" of the concrete floor, *not* near the bottom. The reason for this is that water pressure from beneath the floor tends to make the floor convex on its top side thereby placing the rods in tension. Also, as indicated, tie the anchor to the reinforcing rods.

*Contributed by W. F. Schaphorst, M. E., Newark, N.J.

If the area of the floor is considerable, use several anchors. The object of the anchor is to add the weight of the ground beneath the floor to the weight of the floor itself. Should you wish to do your own computing, figure 100 lb. per cu. ft. as the weight of the ground and 62.5 lb. per cubic foot as the weight of water. You will find that by placing the anchor or anchors down the distance indicated in the sketch you will have correct "balance".

Disposal of Industrial Waste

"Treatment and Disposal of Industrial Waste Waters" is the title of a recent book published by the British Department of Scientific and Industrial Research.

The book includes information on experimental work performed at the DSIR Water Pollution Laboratory, as well as data and information on various methods of treatment which have been tried in a number of industries. It is the first such book in more than three decades.

Copies of the book may be obtained from the British Information Services, New York 20, N.Y., for $3.65 a copy.

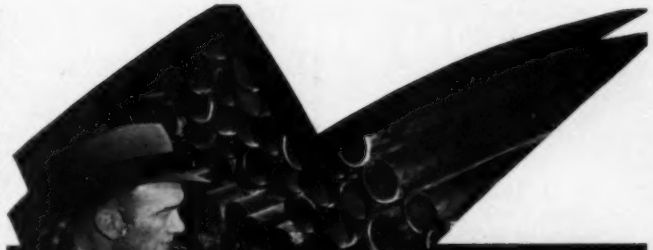
MANUFACTURERS' and EQUIPMENT NEWS

501

Water Control Protective Device

Electro Chemical Supply & Engineering Co., Emmaus, Penna., has announced a new kind of Electrical Control designed as a safety device to protect water-cooled, electrically-operated equipment, such as air compressors, vacuum pumps and the like, against damage through water failure.

The Esto Water Control can be adjusted to operate at any water flow the equipment requires. This eliminates the possibility of overheating. If the water supply fails, a weighted lever falls which opens the circuit and



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CARLON'S flexibility and extreme light weight provide for more rapid and economical installation. One man can lay long sections easily and then make connections in two minutes. Many fittings necessary for other pipe are completely eliminated.

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CHECK CARLON SIZES • • LENGTHS • • WEIGHT • • STRENGTH

STD. SIZE	O. D.	I. D.	CALCULATED B. P. P. S. I.	WT./FT.	NORMAL SHIPPING LENGTHS
1/2"	0.840	0.622	540 lb.	0.103 lb.	400 ft. coils
3/4"	1.050	0.824	350 lb.	0.140 lb.	400 ft. coils
1"	1.310	1.070	200 lb.	0.181 lb.	300 ft. coils
1 1/4"	1.660	1.380	200 lb.	0.267 lb.	200 ft. coils
1 1/2"	1.900	1.610	200 lb.	0.320 lb.	250 ft. coils
2"	2.378	2.070	170 lb.	0.443 lb.	200 ft. coils
3"	3.504	3.070	165 lb.	0.91 lb.	100 ft. coils
4"	4.504	4.030	150 lb.	1.25 lb.	25 ft. str.
6"	6.630	6.090	115 lb.	2.23 lb.	25 ft. str.

CARLON CP

CARTER PRODUCTS CORPORATION

30132 Mooch Avenue

CLEVELAND 5, OHIO

the relay stops the equipment or sounds an alarm or both.

To obtain further information on this new device, use a Reader Service Card on which is entered the above key number and your name and address.

G. D. Butler Joins Nat. Tech. Labs in N.Y.

Announcement has been made by National Technical Laboratories of the appointment of George D. Butler to the staff of the company's New York Office. Mr. Butler was formerly a physicist in Instrument Research at the Calco Chemical Co.

502

Electrical Control Operated by Water Flow

General Electric Co., Schenectady, N.Y., has announced a new control device which responds to a flow of cold water to open or close an electrical contact. Called a flow interlock, the device measures approximately 2½ x 3 x 7 in. In operation it closes a contact when a flow of water exceeds a preset amount and opens it when the flow falls below the preset amount. Working under this principle, the device actually acts as a fuse in a circuit which depends upon water cooling for protection.

The interlock can be used as a safety device in hot water heaters, welding units, kitchen waste units, transformer cooling, induction heating, etc.

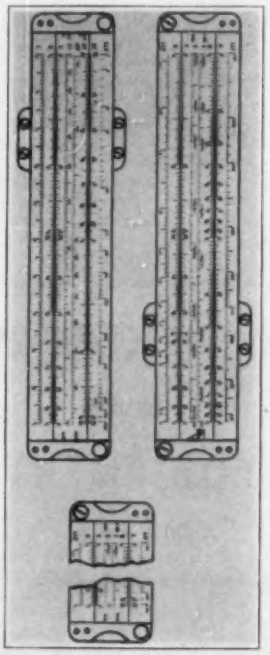
To obtain further information on this unit, mail a Reader Service Card on which is entered the above key number and your name and address.

WACHS NATIONAL PIPE SAW
Tough Cuts MADE EASY
Close quarters — only 14½" between 24" mains.
Two clean square cuts and the pipe comes out.
MAKE FAST AND ACCURATE CUTS ON 12" TO 48" CAST IRON AND STEEL MAINS UNDER THE MOST DIFFICULT CONDITIONS
• Minimum Pipe Line down time.
• Cuts under water in flooded ditches.
• No broken pipe, milled cut.
• Thor Air-Powered, no flames near pipe.
• Set-up time about 15 minutes.
• Portable — weighs only 265 lbs. Two men can carry and set up unit.
• Small excavation — only 14" clearance needed.
• One machine cuts all pipe sizes from 12" to 48".
• Only two adjustments necessary for size changes.
Water Departments must make tough cuts during construction work and for emergency repairs. This one portable machine will handle all your pipe cuts from 12" diameter and up. You will not only save time and labor, but you will get tight joints because of the square milled cut. Cuts cement lined pipe too. This machine is a budget must for 1950.
Write today for descriptive folder and engineering data on this new labor saving saw.
THE E. H. WACHS COMPANY
1525 NORTH DAYTON STREET CHICAGO 22, ILLINOIS

503

6-Inch Log Slide Rule

Pickett & Eckel, Inc., 7 S. Wabash Ave., Chicago 3, Ill., has introduced



a new 6-inch Duplex Type All-Metal Log-Log slide rule, bearing the regular 10-inch Log-Log arrangement. The new rule incorporates the 16-scale arrangement.

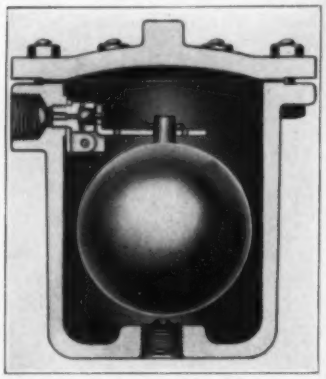
For further information on this unit, use a Reader Service Card on which is entered the above key number and your name and address.

504

Vent and Drain Valve

Crane Co., Chicago, Ill., has improved its automatic vent and drain

valve to assure more accurate seating and longer life. This improvement was obtained by using a simplified ball-type seating mechanism instead



of the customary disc. The valve is easy to install in water and oil piping systems to remove entrapped air, or in compressed air systems to remove water and oil. A complete range of sizes is available to take care of air requirements up to 150 psi. and water up to 125 psi.

For further information, use a Reader Service Card on which is entered the above key number and your name and address.

Site Cast by Universal Concrete Pipe

"Site-Cast" is the modern development of the Universal Concrete Pipe Co. of Columbus, Ohio. The process consists of moving the plant to the site of the project when existing plants cannot furnish specified material. This process was utilized in the construction of a 10-ft. drainage sewer at Midland, Mich.

505

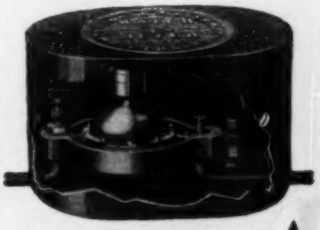
Plastilube Lubricant

The Warren Refining & Chemical Co., Cleveland, Ohio, has developed a new all-purpose lubricant which has no melting point. Plastilube contains none of the usual ingredients of grease. In addition to the non melting feature, it possesses greater adhesive qualities, excellent pumpability at low temperatures and does not break down during working. Plastilube is adaptable for virtually all automotive and industrial uses.

For further information, use a Reader Service Card on which is entered the above key number and your name and address.

CLARK METER BOXES AND COVERS

Left, No. 16 Clark Wonder Lock Meter Box Round....16" and 18" diameters. Large 13" lid.



Above, No. 11 Oval Clark Wonder Lock Meter Box, especially for warmer climates. H-11", L-18", W-12".

Below, A-2-13 Clark Meter Box Cover with screw lock. Height 4", lid opening 13".

Above, A-2-11 Clark Single Lid Meter Box Cover, 4" throat. Also available in 6" and 9" throat.

Below, B-2-11-L Clark Double Lid Meter Box Cover, 6" throat. Also available in 4" and 9" throat.

Above, AA-3-12 Clark Meter Box Cover with 13" Wonder Lock Lid, for use with 15" (illustrated), 18" and 20" box body.

Improved Screw Lock with strong forged bronze bolt.

Wonder Lock Lid (bottom view) showing forged bronze bars.

Perfect Lock of one-piece manganese bronze forging.

write

H. W. CLARK CO.

MATTOON, ILLINOIS

506

Variable Speed Motor

Sterling Electric Motors, Inc., 5401 Anaheim-Telegraph Rd., Los Angeles 22, Calif., has announced a new type of variable speed motor.

Known as the Sterling "Speed-Trol" Vertical Mounted Motor, it incorporates Sterling's Herringbone rotor, labyrinth seals, heavy duty ball bearings, and streamlined case.

The Speed-Trol's power unit is the Klosd-Tite motor. Finger tip control of speed with a large easy-to-read indicator is available. Other advantages of construction features make this variable speed electric power drive especially useful for agitator drives and similar uses.

To obtain further information on this new motor, use a Reader Service Card on which is entered the above key number and your name and address.

507

Noise Abatement

Burgess-Manning Co., Libertyville, Ill., have designed "Snubbers" for engine exhaust and compressor intake noises. They have been used successfully on Diesel, gas and dual-fuel engines in sewage plants, to reduce noise of exhaust slugs without affecting performance.

For further information, mail a Reader Service Card on which is entered the above key number and your name and address.

508

Fluid-Motor Operated Gate Valves

Crane Co., Chicago 5, Ill., has developed a new fluid-motor operated gate valve at low original and low operating cost. Operating on compressed air, water or oil these valves save labor, have greater convenience and have timed operating cycles. The new Crane fluid-motor is a complete compact assembly consisting of a radial diaphragm-type motor, gear

box and yoke. The motor drives the valve through the gear box.

When the valve reaches the end of its travel—either wide open or shut—the motor stalls, automatic shut-off devices are not necessary.

If the pressure actuating the motor should fail the valve can be operated by hand, no de-clutching device is necessary.

PIPE CLEANING TOOLS
FOR WATER LINES
FOR SEWER LINES

Efficient Chain Head Cleaning Auger. A Power-Driven Tool.
"Flexible" Carry-All Trailer, packs everything needed — Rod Reel, Steel Rods, Power Drive, etc.
Above: "Flexible" Power Driven Pipe Cleaning Machine. Fast, Powerful, Safe.
DODGE CITY STREET DEPARTMENT
Application of Power Cleaning Machine and Chain Head Auger in 4" Line.
a few minutes ... for Dodge ... to get at the Root of the trouble with "Flexibles."

"FLEXIBLE"

UNDERGROUND PIPE CLEANING CO. — SEWER-ROD EQUIPMENT CO.
9059 VENICE BOULEVARD, LOS ANGELES 34, CALIFORNIA

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Box 167 Los Nietos, Calif. — 61 Greenway St. Hamden, Conn. — 3786 Durango Ave. Los Angeles 34, Calif. — 709 House Bldg. Pittsburgh 8, Pa. — 4453 S. E. 34th Ave. Portland 2, Ore. — P. O. Box 447 Lancaster, Texas

To obtain further information on this unit, mail a Reader Service Card on which is entered the above key number and your name and address.

509

Portable Tester For Large Meters

The Ford Meter Box Co., Inc., Wabash, Ind., has available a Portable Double-Range Testerate Indicator, a meter testing device for field testing of large meters. The unit includes a lubricated plug valve for adjusting rates of flow, a spring-loaded check valve at the outlet to keep the instrument full of water and four adjustable supporting legs.

For further information, mail a Reader Service Card on which is entered the above key number and your name and address.

510

Coated Cotton Work Gloves

The Milburn Co., 3246 E. Woodbridge St., Detroit 7, Mich., has introduced a new Coated Cotton Work Glove, which has many advantages over synthetic rubber, or other plastic gloves in its chemical resistant properties. Known as "Ply-Glove," this new glove will not crack or peel, it does not become slippery when immersed in oil, water or solvents, and is water, acid, caustic and petroleum solvent proof. These gloves have a long-wearing quality which makes their cost extremely low.

To obtain further information on this glove, which should find considerable use around water and sewage works, use a Reader Service Card on which is entered the above key number and your name and address.

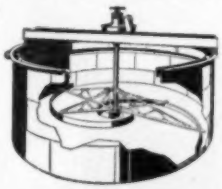
511

Synthetic Resin Cement

The Electro Chemical Supply & Engr. Co., Emmaus, Pa., has announced a new thermal setting synthetic resin cement. Known under the trade name, LECTITE, it is inert to solvents, fats, oils, greases, alkalies, and acids (except at high temperatures). It is particularly useful for jointing acid-proof brick and pipe in the construction of neutralizers, disposal units, tanks, process equipment, etc. It may be stored indefinitely.

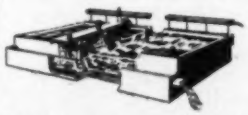
To obtain further information on this resin cement, use a Reader Service Card on which is entered the above key number and your name and address.

CLARIFIERS-THICKENERS



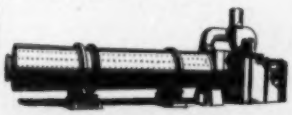
For removal of fine suspended solids from supply water, waste water and sewage. Bulletin 35-C-15.

AUTOMATIC BACKWASH FILTER



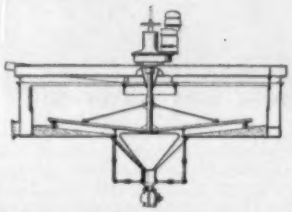
For high removal of non-settling or slow-settling suspended matter. Self-cleaning sand bed. No shutdown necessary for backwashing. Bulletin 46-15.

ROTARY SLUDGE DRYERS



Highly efficient rotary dryers in seven types. Model XH ideal for dehydration of garbage, sewage and sludge. Bulletin 16-D-15.

HYDRO-CLASSIFIERS



For rapid removal of coarse suspended solids from large quantities of waste water. Bulletin 39-B-15.

"Best sanitation equipment made!"

also . . .

RECTANGULAR CLARIFIERS

Especially suited for limited spaces or where sludge delivery is desired at one end of the tank. Bulletin 35-C-15.

DIGESTERS

Sludge scrapers and scumbreaker arms prevent scum accumulation, insure uniform gas production. Emit a dense digested sludge. Bulletin 35-C-15.

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to WATER WORKS and SEWAGE MEN

HOW TO CONTROL ALGAE

"The Use of Copper Sulphate in Control of Microscopic Organisms" by Dr. Frank E. Hale (former Director of Laboratories, Dept. of Water Supply, City of New York) is an authoritative work concerning the control of micro-organisms and elimination of tastes and odors. Describes in detail methods of controlling various forms of microscopic life commonly encountered in water supply systems. Contains descriptive material, plus 48 photo-micrograph studies of organisms discussed.

ROOT AND FUNGUS CONTROL

"Copper Sulphate for Root and Fungus Control in Sanitary Sewers and Storm Drains," by John W. Hood, contains information published for the first time. This material includes actual methods for control and operating procedure. Here's the book that is a "must" for all sewage men.

GET EITHER OR BOTH OF THESE BOOKLETS ABSOLUTELY FREE—
These two valuable booklets, so important to all water works and sewage men, are yours *without obligation*. Mail coupon below!

Write Today, Supply Limited!

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40 Wall Street, New York 5, N. Y.

Please send my free copy of (check one or both):

☐ "Control of Microscopic Organisms"
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Name _____ Title _____
Employed by _____
Address _____
City _____ Zone _____ State _____
WW-550

R. H. Morse, Jr., President Fairbanks-Morse

Robert H. Morse, Jr., the third generation Morse became president

of Fairbanks, Morse & Co. Mr. Morse who has been vice president in charge of operations, started work with the company in 1916. He succeeds his father, Col. Robert H. Morse who became Chairman of the Board. Young Mr. Morse is also president of the Diesel Engine Manufacturer's Association.

512

Line Operated pH Meter

Coleman Instruments, Inc., Maywood, Ill., has announced a new model 30 AC line-operated pH Meter. De-

signed for operation at 95 to 130 volts, 50/60 cycles, this new instrument is characterized by its high stability and almost complete freedom from drift. Accuracy and reproducibility to within 0.05 pH. Continuous, direct reading in pH or Millivolts.

For further information on this new unit, mail a Reader Service Card on which is entered the above key number and your name and address.

513

Deep Well Pump

A. O. Smith Corp., Milwaukee, Wis., has developed a new, small, high efficiency vertical turbine pump using glass-lined bowls and bronze

HUB ENDS . . . FLANGED ENDS . . . UNIVERSAL OR STANDARDIZED MECHANICAL JOINT

Water & Sewerage Works Materials, Catalog 34.

Fire Protection Materials, Catalog 40.

VALVES—A.W.W.A. approved, iron body, bronze mounted with doubled disc parallel seat or solid wedge. Non-rising stem, outside screw and yoke . . . spur or bevelled gear . . . hydraulic or motor operated . . . square bottom and low pressure. Also approved Underwriters and A.F.M. series. Shown above is an M & H 30-inch I.B.B.M. Gate Valve with bevel gears, extended grease case and 4-inch by-pass.

M & H PRODUCTS INCLUDES

FIRE HYDRANTS
GATE VALVES
WALL CASTINGS
SPECIAL CASTINGS
TAPPING SLEEVES AND VALVES
CHECK VALVES
FLOOR STANDS
SPRING LEVER CHECK VALVES
EXTENSION STEMS
ELECTRIC MOTOR OPERATED VALVE
SHEAR GATES
MUD VALVES
FLAP VALVES
SLUDGE SHOES
FLANGE AND FLARE FITTINGS
FLANGED FITTINGS
8 & 5 FITTINGS
CUTTING-IN TEES
HYDRAULIC OPERATED VALVES

M & H VALVE AND FITTINGS COMPANY
ANNISTON, ALABAMA

impellers. The pump, named "Watermaster" is adaptable to deep wells as small as 4-inch diameter and has up to 40 percent more capacity than the average pump in its class.

Equipped with the Smith vertical hollow shaft electric motor, the new unit delivers 15 to 115 gallons per minute. Developed for small community water systems and industrial plants, the "Watermaster" provides high capacity with low cost.

For further information on this unit, mail a Reader Service Card on which is entered the above key number and your name and address.

514

Aluminum Alloy Fittings

The Adalet Mfg. Co., Cleveland, Ohio, has announced production runs

of corrosion resistant aluminum alloy conduit fittings for special application in sewage and water filtration plants. Representative fitting, including weather-proof lighting units are shown in the accompanying photograph.

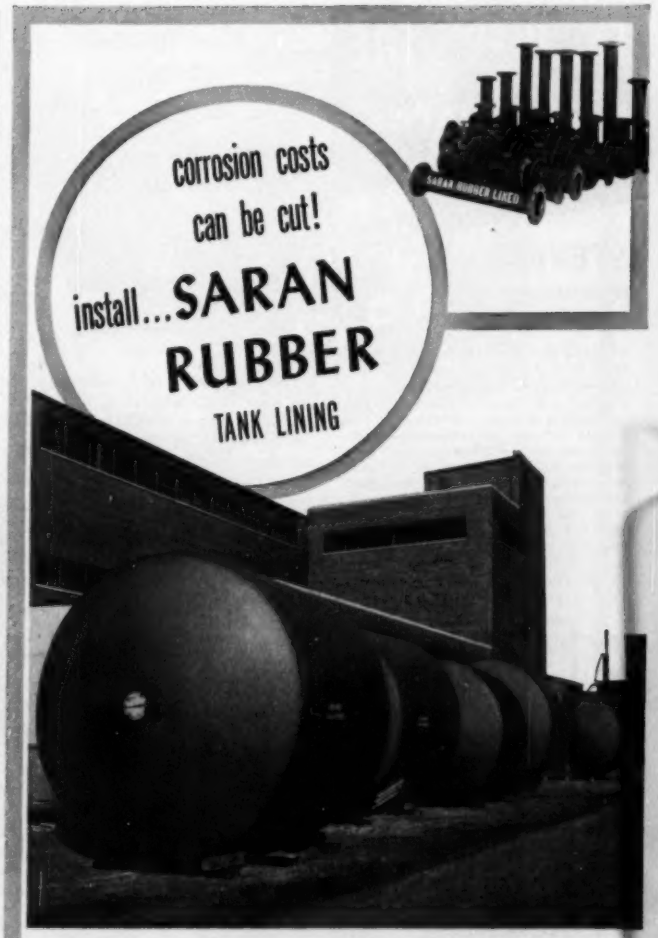
For additional information, mail a Reader Service Card on which is entered the above key number and your name and address.

515

Alum Imported from England

C. Tennant Sons, & Co. of New York have announced that they are importing alum and its related products from the Peter Spence & Sons, Ltd. plant located at Widnes, Lancashire, England. Tennant will warehouse the material in the U.S. to insure prompt service to customers. Now being distributed are an iron-free aluminum sulphate, ammonia alum, and potash alum.

Technical data sheets on these alums as well as samples may be obtained. Use a Reader Service Card on which is entered the above key number and your name and address.



SARAN rubber combines the desirable features of rubber—flexibility and strength—with inherent ability of saran to resist corrosive liquids. Add the high degree of abrasive resistance found in saran rubber and you have an outstanding lining for the storage and conveyance of grease, solvents, acids and chemicals.

Saran rubber can be applied easily and economically by experienced tank lining applicators located strategically throughout the country. Saran rubber lined pipe is available also in 8-inch diameters and larger, and up to 20-feet in length.

Get in touch with an applicator today by contacting your nearest Saran Lined Pipe Company office or find out how you can add many years to the life of your costly equipment by writing Dept. TSP-84.

Distributed by

Saran Lined Pipe Company

701 STEPHENSON BUILDING • DETROIT, MICHIGAN
Offices in: New York • Boston • Philadelphia • Pittsburgh
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Los Angeles • Portland • Cleveland • Denver • Seattle
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SARAN RUBBER
a
DOW
product

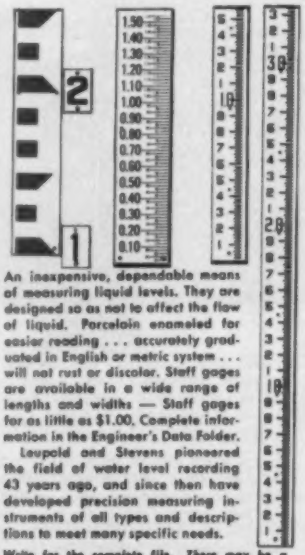
ENGINEER'S FILE ON HYDROGRAPHIC INSTRUMENTS

STEVENS HYDROGRAPHIC INSTRUMENTS

A wide range of precision measuring instruments to record and indicate head, flow, and totalize flow; for waterworks, sewerage, irrigation and industrial uses. New, low cost methods of liquid level recording.

These methods and instruments for all liquid measuring problems are listed in a complete Engineer's Data folder for your convenience. This information folder is FREE and can be had by filling in the coupon below. The folder includes data on instruments to record fluctuations of liquids in oil production, stream gaging, deep wells, sewage, irrigation, etc., both accurately and economically.

STAFF GAGES



An inexpensive, dependable means of measuring liquid levels. They are designed so as not to affect the flow of liquid. Porcelain enameled for easier reading . . . accurately graduated in English or metric system . . . will not rust or discolor. Staff gages are available in a wide range of lengths and widths — Staff gages for as little as $1.00. Complete information in the Engineer's Data Folder.

Leupold and Stevens pioneered the field of water level recording 43 years ago, and since then have developed precision measuring instruments of all types and descriptions to meet many specific needs.

Write for the complete file. There may be a measuring device that exactly suits your specific requirements. Use the coupon below.

Please send me the *Engineer's Data Folder* with complete information on Hydrographic instruments.

Name_____

Address_____

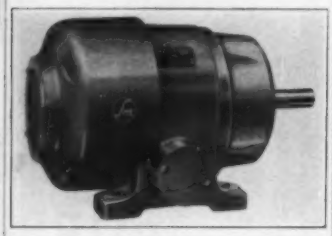
City_____ **State**_____

LEUPOLD & STEVENS INSTRUMENTS, INC.
4445 N.E. Glisan • Portland 13, Oregon

516

Klosd-Tite Motor

Sterling Electric Motors, Inc., Los Angeles, Calif., has announced that their "Klosd-Tite Fan-Cooled" motor



is now available with face mounted end bracket having NEMA style "C" dimensions in ¾ to 20 hp. incl. Obtainable in either the footless type or standard horizontal type with feet, these face mounted motors are ideal for close coupled pumps or blowers, etc.

For further information, mail a Reader Service Card on which is entered the above key number and your name and address.

517

Nalcite HCR

National Aluminate Corp., Chicago 38, Ill., has developed a new zeolite, Nalcite HCR, for removal of residual hardness after the hot process lime-soda softening. This zeolite is not adversely affected by hot water.

To obtain further information on Nalco's Nalcite HCR, mail a Reader Service Card on which is entered the above key number and your name and address.

LITERATURE AND CATALOGS

518

WELL SUPPLY CATALOG

National Supply Co., Pittsburgh, Penna., has issued a 110-page booklet entitled **Composite Water Well Supply Catalog.**

The new catalog lists all the equipment necessary to drill and produce a well. It is designed to serve as a complete reference book for operators' requirements.

To obtain a copy of this complete catalog of well supplies, mail a Reader Service Card on which is entered the above key number and your name and address.

3 way dependability

1. **IN CASE OF FIRE**—dependable, smooth operation . . . clear, large waterways . . . insure plenty of water. Hydrants open fast and easily *with* the pressure . . . and close without water hammer.
2. **IN CASE OF ACCIDENT**—stem held in place below main valve means no water loss due to a bent stem. One man can easily remove all operating mechanism for inspection or repairs.
3. **IN CASE OF LOW TEMPERATURES**—Eddy's positive drip action automatically drains hydrant barrel of all water when hydrant is closed . . . safeguards hydrant against freeze-ups.

EDDY
VALVE COMPANY
WATERFORD NEW YORK

A subsidiary of James B. Clow & Sons

519

FILTER BOTTOMS

F. B. Leopold Co., Inc., Pittsburgh, Penna., has issued a bulletin on **Leopold Filter Bottoms.** This eight page folder contains a discussion of the Leopold underdrain, its construction, its general features, and its use. A table showing loss of head through Leopold Compound Duplex Filter Bottoms is also shown. Typical layouts and plans for installation are also given as are typical specifications.

To obtain a copy of this bulletin, mail a Reader Service Card on which is entered your name and address and the above key number.

520

SEWAGE SCREEN

Green Bay Foundry and Machine Works, Green Bay, Wis., has available a four page bulletin on the **"North" Sewage Disposal Screen.** The bulletin gives the advantages of the screen, capacities for the four different sizes, points on the operation of the screen, and drawings of the screen design.

To obtain a copy of this folder, mail a Reader Service Card properly filled in with the above key number and your name and address.

521

DIESEL ENGINES

The Superior Engine Division of the National Supply Co., Springfield, Ohio, has issued a new bulletin on the **Superior Diesel** For Stationary Application. This 20-page bulletin presents more than 100 engine specifications showing a wide range in power. Also featured are 60 years of Superior Engine research and production development and numerous installations of these engines in the past few years in municipal and utility plants.

To obtain a copy of this bulletin on Diesel Engines, mail a Reader Service Card on which is entered the above key number and your name and address.

522

CORROSION SERVICE PIPING

Taylor Forge & Pipe Works, Chicago, Ill., has issued a bulletin on **Corrosion Service Piping,** which is a comprehensive treatment on stainless steel and nickel alloy anti-corrosion and anti-contamination piping. The 32-page bulletin includes discussions of economics, standards, advantages of welding, technical data, and design tips. Complete di-

WARREN
Solves Your
PIPE
PROBLEMS
BELL & SPIGOT PIPE • FLANGE PIPE • MECHANICAL JOINT PIPE • FLEXIBLE JOINT PIPE • SPECIAL CASTINGS • SHORT BODY BELL & SPIGOT SPECIALS •
Warren Cast Iron Pipe and Fittings can be supplied in all sizes 2" to 84" with all types of joints and in accordance with Standard Specifications. Specify "Warren Pipe" for your next job.
Take advantage of our large stock of non-standard patterns, when in need of special castings to meet your individual requirements.
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WARREN PIPE CO. of MASS. INC.
75 FEDERAL ST., Boston, Mass.

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AND
INDUSTRIAL WATER TOWERS
SPEELMON ELEVATED TANK—SERVICE
COMPLETE PAINTING AND REPAIR SERVICE
822 N. Court St. Rockford, Ill.

Phipps & Bird
LABORATORY MIXER
IS the important piece of equipment in the Modern Water Works Laboratory. Now being used by leaders in water works research. Many superintendents and chemists have been able to reduce their chemical costs by the control of chemical dosages with this mixer. Write for literature.
PHIPPS & BIRD, INC. Richmond, Va.

Starting Point

for Economical Water Treating Plants

Increase throughput capacity—in your present water treating plant without additional construction costs. Coagulate with the aid of N-Sol Process (activated silica).*

N-Sol produces large, tough and heavy floc. It shortens settling time; often lengthens filter runs.

Before you complete designs on new or enlarged filtration plants, get file #52-8 on "N-Sol Processes."

*made by reacting "N" Silicate with ammonium sulphate, chlorine, alum or sodium bicarbonate.

PHILADELPHIA QUARTZ COMPANY
1166 Public Ledger Bldg., Philadelphia 6, Pa.

N-SOL Coagulating Aids

NOW! FASTER, EASIER JOINTING

of Cast Iron Bell & Spigot Pipe

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PLASTICIZED, SULPHUR BASE COMPOUND

Comes in form of small waterproof wedges. Needs no breaking up, as do ingots. Saves melting time.

Wedgetite is *more* free-flowing. Formula includes germicide which inhibits attack by sulphur oxidizing bacteria. Shipped in 100 lb. laminated heavy duty, waterproof bags.

This package will not disintegrate when wet.

Wedgetite delivers lastingly tight joints with sufficient flexibility to absorb vibration and to meet ground movement. Write for more information.

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752 Broad Street — Emmaus, Penna.

First Producer of Thiokol Plasticized Sulphur Cements
Manufacturers of DURO-SEAL *Asphalt Jointing Material for Sewer Pipe*

mensional information is given on stainless fittings and flanges.

To obtain a copy of this bulletin mail a Reader Service Card on which is entered the above key number and your name and address.

523

WATER WELL TESTER

Fisher Research Laboratory, Inc., Palo Alto, Calif., has published a bulletin on **Salt Water Infiltration** and the Fisher M-Scope water well tester. This bulletin describes the salt water problem and the four methods commonly used for testing for salt water infiltration in a well. The Fisher M-Scope water well tester is described, its principles of operation explained and its application to the problems outlined.

To obtain a copy of this bulletin, use a Reader Service Card on which is entered the above key number and your name and address.

524

FREFLO PUMPS

Worthington Pump and Machinery Corp., Harrison, N.J., has available a bulletin on Worthington **Freflo Pumps.** The bulletin describes this type of pump which comes in three models and is offered for pumping sewage. Horizontal, vertical and vertical close coupled models are available. The bulletin shows cutaway diagrams, and performance curves.

To obtain a copy of this bulletin, use a Reader Service Card on which is entered the above key number and your name and address.

525

LABORATORY EQUIPMENT

Fisher Scientific Co., Pittsburgh, Pa., has issued a bulletin on **Castaloy Laboratory Appliances** which include burette holders, burette supports, utility clamps, extension clamps, flexaframe supports, clamp holders, devices for controlling flow and many other useful items for use in laboratory.

If you are interested in modern equipment for a laboratory, use a Reader Service Card on which is entered the above key number and your name and address.

526

LIQUID LEVEL CONTROLS

B/W Controller Corp., Birmingham, Mich., has available a four page bulletin on all electric floatless **Liquid Level Controls.** This bulletin shows the principle and operation of

the B/W Relay, its features, and typical uses, including water and sewage pumpings. Also shown are photographs, descriptions, and specifications of induction relays, induction relay switches, relay enclosures, starter and relay combinations, multiple pump controls, electrode holders, and special controls and panels.

To obtain a copy of this bulletin, mail a Reader Service Card on which is entered the above key number and your name and address.

527

TRENCHLINER

Parsons Co., Newton, Iowa, has announced the publication of a new catalog describing the latest improvements and capacities of the **Parsons 250 Trenchliner.** This 8-page bulletin contains photographs depicting many exclusive features, along with schematic drawings listing the detailed dimensions of the machine.

Trenching for water and sewage lines is a big job in the operation of water and sewage systems, and it is important to have a trencher that is big, tough, and will cut through all types of material short of solid rock. This bulletin describes such a machine.

To learn more about this machine send for this bulletin on the Parsons Trenchliner. Just mail a Reader Service Card on which you have written the above key number and your name and address.

528

VIBRATING SCREEN

Link-Belt Co., Philadelphia, Penna., has available a catalog bulletin on the **Link-Belt Liquid Vibrating Screen.** The bulletin describes and shows this equipment being used for the separation of solids and liquids in canning wastes and elsewhere.

To obtain a copy of this bulletin, fill in a Reader Service Card with the above key number and your name and address and mail the card to this magazine.

529

ROTARY DISTRIBUTORS

Walker Process Equipment, Inc., Aurora, Ill., has released a four page bulletin on **Rotoseal Rotary Distributors** for trickling filters. This bulletin shows the design of the Rotoseal distributor, and describes its features.

To obtain a copy of this bulletin, mail a Reader Service Card on which is entered the above key number and your name and address.

Which shall it be? Disposing of unwanted sludge by burial or burning is definitely an expense item. The same sludge processed with a Royer becomes a readily saleable fertilizer — a steady source of income.

Undried sludge cake with as much as 56% moisture content can be shoveled into the hopper of a Royer Sludge Disintegrator, along with added chemicals if desired. A thoroughly mixed, finely granulated fertilizer is discharged, with all sticks, stones and trash removed—ready for immediate use by parks, florists and golf courses.

Royers are made in electric motor, gasoline engine or belt-to-tractor driven models and in sizes from 1 to 12 cubic yards per hour. Write for complete information.

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a clear liquid penetrating (1"+) sealer for concrete and masonry preventing water absorption and reducing the action of acids. Holds 12' hydrostatic head. Use our Hayproc Rubberized Enamel for color on walls and floors—not affected by concentrated acids, alcohol, oil, or traffic abrasion.

30 OTHER PRODUCTS
Write for technical data.
Haynes Products Co., Omaha 3, Nebr.
See our file in Sweet's

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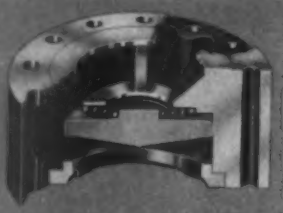

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Write for Bulletin WH 100

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530

PUMP CATALOGS

Economy Pumps, Inc., Hamilton, Ohio, has three new pump catalogs available. These include the general service Sump Pumps, Mixed Flow Volute Pumps, and Non Clogging Centrifugal Pumps.

To obtain these catalogs, use a Reader Service Card on which is entered the above key number and your name and address. Also indicate which catalog or catalogs you desire.

531

HARDINGE "HIGHLIGHTS"

Hardinge Co., Inc., York, Penna., has published its first issue of **Hardinge Highlights,** a four page company magazine or house organ. Included in this first issue is a short story on the Hardinge Clarifiers at the Columbus, Ohio, water softening plant. "Charlie" Hoover, Supt. of Filtration, and M. Hough, Supt. of Water Dept. at Columbus, are shown with Harlowe Hardinge, president of the company. The Hardinge Highlights also contains the prize winning photographs of the 1949 contest, and a story on the Hardinge 25 year club as well as other company activities.

If you desire to have your name on the mailing list for the Hardinge Highlights, mail a Reader Service Card on which is entered the above key number and your name and address.

532

DE LAVAL PRODUCTS

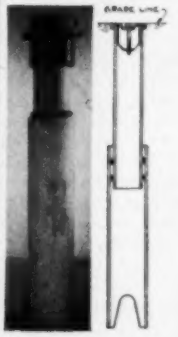
De Laval Steam Turbine Co., Trenton 2, N.J., has available a complete pictorial bulletin of **Products of De Laval.** Pictured and described are steam turbines, helical gears, centrifugal pumps for water and sewage, multistage pumps, Imo pumps, blowers and compressors, and worm gear speed reducers.

To obtain a copy of this bulletin, use a Reader Service Card on which is entered the above key number and your name and address.

533

THE YEOMANS GUARD

Yeomans Bros. Co., Chicago, Ill., regularly issues **The Yeomans Guard,** a house organ devoted to company products, activities, and installations of equipment. The most recent issue contains an illustrated story on the solving of the sewage treatment problem of Florida's Silver Springs. This is but one of the items in the February-March issue.



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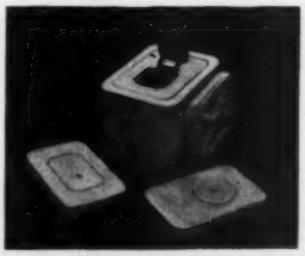

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SAN DIEGO, CALIF. — PHOENIX, ARIZ.

To have your name added to the mailing list for the Yeomans Guard, just mail a Reader Service Card on which is entered the above key number and your name and address.

534

CHLORINATION TOPICS

Wallace & Tiernan's **Chlorination Topics,** Vol. 4, No. 1 contains some interesting stories on the flow chart of the Ottumwa, Iowa, water plant, cyanide waste treatment with chlorine, mussel trouble at a power station and laboratory studies on the treatment of phenol wastes with chlorine.

In addition this 8-page house organ contains a current literature review and an interesting feature "Who and What" by A. E. Griffin.

To have your name added to the mailing list for "Chlorination Topics," use a Reader Service Card on which is entered the above key number and your name and address.

535

CORROSION RESISTING PLUG VALVES

The Duriron Co., Inc., Dayton, Ohio, has issued bulletins on a new line of **Durco Corrosion Resisting Plug Valves.** These bulletins consist of two single sheets, punched for ring binder. One sheet presents the Type B-175 lb. lubricated straightway valve and the other shows the Type B with flexible jointed plug.

To obtain these sheets, use a Reader Service Card on which is entered the above key number and your name and address.

536

VALVE SIZING CHARTS

Fischer & Porter Co., Hatboro, Penna., has issued liquid and gas **Valve Sizing Charts,** covering the ranges 0.02 to 10,000 gpm. and 1 to 100,000 lb. per hr. respectively.

To obtain a copy of these charts, use a Reader Service Card on which is entered the above key number and your name and address.

537

TYGON TUBING

U.S. Stoneware, Akron, Ohio, has just released a bulletin on **Tygon Flexible Plastic Tubing.** This 24-page catalog describes the many and varied uses to which this tubing can be put, including laboratory uses in water and sewage plants. The tubing is clear, inert, flexible, non-toxic, non-aging, and sterilizable. According to the bulletin, there are six

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Buffalo-Made
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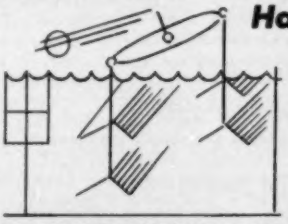

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6	2.5	3.00	2.25	11.71
8	2.5	4.00	2.25	14.63
10	2.5	5.00	2.25	17.70
12	2.5	6.00	2.25	20.86
14	2.5	7.00	2.25	24.02
16	2.5	8.25	2.25	33.07
18	2.5	9.25	2.25	36.88
20	2.5	10.50	2.25	40.71
24	2.5	13.00	2.50	53.02
30	2.75	16.00	2.50	65.36
36	2.75	19.00	2.50	77.96
48	3.50	30.00	3.00	121.15
54	4.0	38.00	3.00	135.60
60	4.0	42.00	3.00	150.70

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No Caulking

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TYPE "A"

Type "A" Roto-Trol operates from the pressure in the pump discharge line, at the pump house. The electric time delay prevents starting or stopping due to surges. It also protects deep well turbines from damage due to back-spin. . . . *Type "A" Multi-Pump Roto-Trol* is designed for two or more pumps discharging into the same discharge pipe. Adjusted time delays compensate for additional pumping friction and surges when second pump starts or stops.

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standard Tygon formulations. Complete data are given on each one. In addition, the bulletin gives the chemical resistant characteristics of these and other special formulations. One section of the bulletin tells all about laboratory uses, and industrial applications.

To obtain this interesting bulletin, mail a Reader Service Card on which you have written your name and address and the above key number.

538

SPIRAL-WELD PIPE

Taylor Forge & Pipe Works, Chicago, Ill., has issued a bulletin on the **Taylor Spiral-Weld Pipe.** This bulletin shows the sizes and wall thickness which are available, and also shows Taylor Forge fittings which are intended for use with spiral-weld pipe. Also listed in the 4-page folder are many typical applications for this light weight pipe which has great strength.

To obtain a copy of this bulletin on spiral-weld pipe, use a Reader Service Card on which is entered the above key number and your name and address.

539

IMPORTED BOOKS

The Book Dept. of Mapleton House, Brooklyn, N.Y., has issued a small catalog listing well known imported books on sanitation and sanitary engineering, water supply, pumps and mechanical engineering. These books are now available at savings up to 45 per cent.

If you are interested in building up your library of technical books, obtain one of these catalogs by mailing a Reader Service Card from the back of this magazine. Be sure to enter both your name and address AND the above key number.

540

ENERGY CONTROL

Energy Control Co., New York, N.Y., issues a bi-monthly house organ. Titled **Energy,** this "bulletin" is packed full of stories about the equipment which this company handles. One of the recent issues had a story about water metering, in particular about the Buffalo Meter Co. Niagara water meters.

Energy Control Co. represents The Hays Corp. (recorders); Bethlehem Fdry. and Mach. Co. (flow tube); Cochrane (condensate return); Foster (pressure reducing, etc.); ESS (photoelectric controls); Lonergan (pressure and vacuum gages); De Zurik (eccentric plug valves); Penn

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These "news magazines" will be of interest to persons having problems in the measurement or control of energy. To have your name placed on the mailing list, just enter the above key number and your name and address on a Reader Service Card and mail it to this magazine.

541

REGULATORS AND CONTROLLERS

Fisher Governor Co., Marshalltown, Iowa, has issued a bulletin on **Fisher Regulators and Controllers.** Included in the 12-page catalog are pressure regulators, diaphragm control valves, pump governors, gas regulators, liquid level controls, lever and float valves, traps, strainers and filters and special control valves.

To obtain a copy of this catalog, mail a Reader Service Card on which is entered the above key number and your name and address.

542

SUBDRAIN PIPE

The Firman L. Carswell Mfg. Co., Kansas City, Kas., has issued a bulletin on **Free Flow Subdrain and Runoff Pipe.** The bulletin describes free flow pipe for sub-drains, gives dimensions, discusses efficiency, and shows various uses of the pipe for removing underdrainage. Suggestions are given for construction of sub-drains.

To obtain a copy of this useful book, use a Reader Service Card on which is entered the above key number and your name and address.

543

COMPRESSIBILITY CHARTS

Worthington Pump and Machinery Corp. has released a new Worthington Research Bulletin. This one is titled **Compressibility Charts and Their Application** to Problems Involving Pressure—Volume Energy Relation for Real Gases. A 26 page bulletin, this material is divided into three parts: I—Real Gases, II—Horsepower Equations for a Real Gas, and III—Flow Through Nozzles. Illustrative charts and diagrams are included.

The purpose of the bulletin is to present a series of compressibility charts covering the very broad pressure-temperature range usually encountered in engineering practice.

(*Continued on page* 148a)

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The progress picture above shows a stage of our repair work on a concrete water tank in New England. This tank was completely lined with reinforced "GUNITE" to stop seepage which had caused serious disintegration to the exterior of the tank. The entire outside of the tank was subsequently chipped and existing hoop rods exposed.

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(If you counted only 34 words, you probably didn't realize that "economical" and "proved" are doubly important in connection with the Bio-Chemical Process)

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(*Continued from page* 145A)

The charts are especially complete at low values of reduced pressure.

This bulletin with all of its mathematical developments will be of greatest interest to engineers, particularly those working in the field of gas compression.

To obtain a copy of this bulletin, use a Reader Service Card on which is entered the above key number and your name and address.

548

TRI-CLAD GENERATORS

General Electric Corp., Schenectady, N. Y., has issued a bulletin on the G.E. **Tri-Clad High Speed Synchronous Generators.** This eight page bulletin deals with generators for standby, portable, and prime source power is widespread fields of application. Three typical installation stories are presented along with construction features, mechanical modifications and performance data.

To obtain a copy of this bulletin, use a Reader Service Card on which is entered the above key number and your name and address.

549

HOT PROCESS SOFTENERS

Graver Water Conditioning Co. has just issued a comprehensive bulletin on **Hot Process Water Softeners.** An introductory section explains boiler plant troubles caused by impurities in water. Twelve different methods of heating water to eliminate these impurities are presented as are the advantages and chemistry of hot-process softening.

Also given are two basic designs and six adaptations of each design to various plant conditions. More than 30 diagrams and flow charts are shown together with many installation photographs.

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32 W Maple Street

WATER & SEWAGE WORKS
Chicago 10, Illinois

550

CONSTRUCTION PUMPS

Marlow Pump Co., 523 Greenwood Ave., Ridgewood, N. J., has just issued a 12-page bulletin on seventeen different series of self-priming centrifugal pumps and three series of diaphragm pumps especially designed for use in construction work.

In the line of self-priming centrifugals described is the newest Marlow Water Wizard Pump for contractors, the Series 430, 40M, 4-inch suction and discharge.

The bulletin contains performance tables stating the capacities in gallons per minute at heads from 15 to 110 feet for the low-pressure (at AGC Rating) and 40 to 280 feet for the high-pressure self-priming centrifugals.

For a copy of this bulletin, enter the above key number on a Reader Service Card and mail.

551

TRAVELLING WATER SCREENS

Chain Belt Co. of Milwaukee has published a catalog on the **Rex Travelling Water Screens.** The bulletin shows how these screens are effectively used to screen debris from intake water. The various types of screens available are shown, together with the features of the Rex design

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and the facts to consider in selecting the right type of screen.

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544

MERCURY MANOMETER FLOW METERS

Fischer & Porter Co., Hatboro, Penna., has issued a new bulletin on the **Mercury Manometer Flow Meters.** The bulletin describes the several models available: close-coupled magnetic clutch, with or without pneumatic transmission to a remote location—electric impedance bridge transmitter and automatic ratio control. Specifications and dimensions are given.

To obtain a copy of this bulletin, use a Reader Service Card on which is entered the above key number and your name and address.

545

SWIMMING POOL FITTINGS

Josam Manufacturing Co., Cleveland, Ohio, has published a 32-page **Swimming Pool Drainage Products Manual SP-3.** The booklet contains ideas and suggestions on modern pool layouts together with complete details on correct drainage fittings to be used in the construction of new pools or remodeling of old pools.

To obtain a copy, use a Reader Service Card on which is entered the above key number and your name and address.

546

BUTTERFLY VALVES

Automatic Temperature Control Co., Inc., Philadelphia, Penna., has issued a folder on **Butterfly Valves** for the control of air, gas, water, and steam. Diagrams are shown and prices are given.

To obtain a copy of this folder, mail a Reader Service Card on which is entered the above key number and your name and address.

547

VIBRATORY FEEDERS

Syntron Co., Homer City, Penna., has just issued a new bulletin on **Vibratory Feeders.** The bulletin shows and describes "Vibra-Flow" Vibratory Feeders, Long Conveyors, Multiple Magnet Models, Furnace Feeders, Infra-Red Dry Feeders, etc.

To obtain a copy of this new bulletin, mail a Reader Service Card on which is entered the above key number and your name and address.

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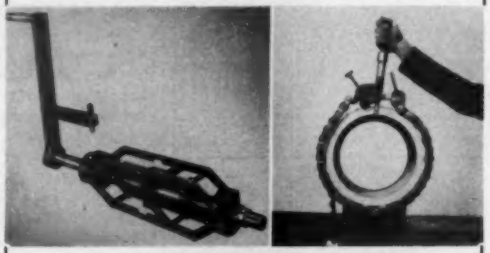

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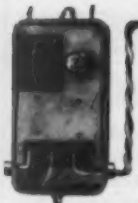

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WATER & SEWAGE
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REFERENCE & DATA SECTION

1950

Foreword

In the past we have repeated useful basic data, tables, graphs, etc.—from year to year, chiefly for the benefit of new subscribers; certain other matter was repeated in alternate years or every third year, and new material was, of course, added. Thus the subscriber who kept three consecutive Reference and Data issues on file had all of the most important reference material published by Water & Sewage Works.

This year very little material is repeated from previous issues, but considerably more new material is being published.

In order to have a complete Reference and Data file it will be necessary for the readers to have available not only the current issue but also issues of at least the four years preceding this issue. Several articles published since 1941 have not been repeated within the last four years. Therefore for the convenience of the user a consolidated ten year index is incorporated in this issue.

CLASSIFIED INDEX of PRODUCTS

FOR THE INDEX TO THE REFERENCE AND DATA MATERIAL, AND THE INDEX TO ADVERTISERS, SEE THE REAR SECTION OF THIS ISSUE.

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Dracco Corp., Cleveland, Ohio.
Frank G. Hough Co., 752 Sunnyside Ave., Libertyville, Ill.
Jeffrey Mfg. Co., 906 N. 4th St., Columbus, Ohio.
Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

BAR SCREENS
(See Screens, Sewage)

BINS, STORAGE
Hammond Iron Works, Warren, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Posey Iron Works, Inc., 540 S. Prince St., Lancaster, Pa.

BITUMINOUS COATINGS AND LININGS
Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Atlas Mineral Prod. Co., Mertztown, Pa.
Centriline Corp., 140 Cedar St., New York 6, N. Y.
Ebony Paint Manufacturing Co., 18th and Agnes Ave., Kansas City 1, Mo.
Inertol Co., Inc., 486 Frelinghuysen Ave., Newark 5, N. J.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Wailes Dove-Hermiston, Westfield, N. J.

BLACK ALUM
Activated Alum Sales Corp., 516 N. Charles St., Baltimore 1, Md.

BLEACHING POWDER
(See Calcium Hypochlorite)

BLOWERS, AIR, GAS (Centrifugal and Rotary)

Allen-Billmyre Div., Lamson Corp., 1661 S. Clinton St., Syracuse, N. Y.
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
De Laval Steam Turbine Co., Trenton 2, N. J.
Dracco Corp., 4079 E. 116th St., Cleveland 5, Ohio.
General Electric Co., Schenectady, N. Y.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Homelite Corp., Riverdale Ave., Port Chester, N. Y.
Roots-Connersville Blower Corp., P. O. Box 827, Connersville, Ind.
Standard Stoker Co., Erie, Pa.
U. S. Hoffman Mach. Corp., 111 Fourth Ave., New York 3, N. Y.

BLOWERS (Gasoline Engine Driven Portable)

Allen-Billmyre Div., Lamson Corp., 1661 S. Clinton St., Syracuse, N. Y.
Homelite Corporation, Riverdale Ave., Port Chester, N. Y.
Roots-Connersville Blower Corp., P. O. Box 827, Connersville, Ind.

BOILER FEEDWATER TREATMENT AND EQUIPMENT

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 54, Calif.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Liquid Conditioning Corp., 114 E. Price St., Linden, N. J.
Milton Roy Co., 1329 E. Mermaid Lane, Philadelphia 18, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Penn.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.

BOILERS, GAS

American Radiator & Standard Sanitary Corp., P. O. Box 1226, Pittsburgh 30, Pa.

BOOKS, TECHNICAL

McGraw-Hill Book Co., 330 W. 42nd St., New York 18, N. Y.
The MacMillan Co., 60 Fifth Ave., New York 11, New York.
John Wiley & Sons, Inc., 440 4th Ave., New York 16, N. Y.

BOXES, VALVE AND METER

(See Valve Boxes; Meter Boxes)

BRASS GOODS

(See also Pipe, Brass)
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Glauber Brass, Inc., Kinsman, Ohio
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
A. Y. McDonald Mfg. Co., Dubuque, Iowa
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Walsbach Corp., 1500 Walnut St., Philadelphia 2, Pa.

BREECHINGS, STEEL

Chicago Bridge & Iron Company, 2196 McCormick Bldg., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Posey Iron Works, Inc., 540 S. Prince St., Lancaster, Pa.

BUFFER SOLUTIONS & TABLETS

Coleman Instruments, Inc., 313 Madison St., Maywood, Ill.
Hellige, Inc., 4718 Northern Blvd., Long Island City, N. Y.
La Motte Chemical Co., Towson, Baltimore 4, Md.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.

BUCKET ELEVATORS

Chain Belt Co., 1610 W. Bruce St., Milwaukee, Wis.
Dorr Co., Barry Place, Stamford, Conn.
Link-Belt Co., 2045 Hunting Park Ave., Philadelphia 40, Pa.

BUTTERFLY VALVES

(See Valves, Butterfly)

CABLE

General Electric Corp., Schenectady, N. Y.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

CALCIUM HYPOCHLORITE

Innis, Speiden & Co., 117 Liberty St., New York City.
John Wiley Jones Co., Caledonia, N. Y.
Mathieson Chemical Corp., 60 E. 42nd St., New York 17, N. Y.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, Fifth Ave. at Bellefield, Pittsburgh 13, Pa.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Day St., New York 7, N. Y.

CALGON

(See Corrosion Suppression and Water Stabilization)

CAULKING MACHINES & TOOLS

Mueller Co., 512 W. Cerro Gordo St., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York 7, N. Y.

CARBON-ACTIVATED

(See Activated Carbon)

CARBONATORS (Recarbonation).

Amer. Water Softener Co., Philadelphia 33, Pa.
Amer. Well Works, 100 N. Broadway, Aurora, Ill.
Carborundum Co., Perth Amboy, N. J.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Walker Process Equipment Co., 518 Hankes Ave., Aurora, Ill.

CASTINGS, IRON, STEEL, ALLOY STEEL, ETC.

Bethlehem Fdry. & Machine Co., Bethlehem, Pa.
Blackburn Smith Mfg. Co., 95 River St., Hoboken, N. J.
Cast Iron Pipe Research Assoc., 122 So. Michigan Ave., Chicago 3, Ill.
Central Foundry Co., 246 Fourth Ave., New York, N. Y.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hardinge Mfg. Co., 240 Arch St., York, Pa.
Josam Mfg. Co., 1302 Ontario St., Cleveland 13, Ohio.
Posey Iron Works, Inc., 540 S. Prince St., Lancaster, Pa.
Richmond Fdry. & Mfg. Co., P.O. Box 5156, Saunders Sta., Richmond, Va.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N.J.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.

CAST IRON PIPE

(See Pipe)

CATHODIC PROTECTIVE SYSTEMS

Electro Rust-Proofing Co., Belleville, N. J.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Wallace & Tiernan, Belleville 9, N. J.

CAUSTIC SODA

Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich.
Hooker Electrochemical Co., 9 Union St., Niagara Falls, N. Y.
Mathieson Chemical Corp., 60 E. 42nd St., New York 17, N. Y.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, Fifth Ave. at Bellefield, Pittsburgh 13, Pa.
Solvay Sales Corp., 40 Rector St., New York City.

CEMENT ASBESTOS PIPE

H. D. Fowler Co., Inc., 901 Lane St., (P. O. Box 3084), Seattle, Wash.
Keasbey & Mattison Co., Ambler, Pa.
Johns-Manville, 22 E. 40th St., New York City.

CEMENT GUN

Cement Gun Co., Allentown, Pa.
Preload Corp., 211 E. 37th St., New York 16, N. Y.

CEMENT PIPE

(See Pipe, Concrete)

CEMENT LINED PIPE

(See Pipe)

CEMENT LINING OF PIPE

Centriline Corp., 140 Cedar St., New York 6, N. Y.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

CEMENTS, ACID PROOF

Atlas Mineral Prod. Co., Mertztown, Pa.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Robinson Clay Product Co., 65 W. State St., Akron, Ohio.

CEMENTS, REFRACTORY

Carborundum Co., Refractories Div'n., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.

CEMENTS, SEWER PIPE

Atlas Mineral Prod. Co., Mertztown, Pa.
Preload Corp., 211 E. 37th St., New York 16, N. Y.

CEMENTS, WATER MAINS

Atlas Mineral Prod. Co., Mertztown, Pa.
Michael Hayman & Co., 870 E. Ferry St., Buffalo, N. Y.
Northrop & Co., Inc., Spring Valley, N. Y.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

CHAINS (Elevating, Conveying & Power Transmission)

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

CHEMICAL CONVEYING EQUIPMENT

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dracco Corp., 4079 E. 116th St., Cleveland 5, Ohio.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

CHEMICAL FEEDING & PROPORTIONING EQUIPMENT

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders - Providence, Inc., 345 Harris Ave., Providence 1, R. I.
B/W Controller Corp., 2306 E. Maple Rd., Birmingham, Mich.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 54, Calif.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Fischer & Porter Co., Hatboro, Pa.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. 3084, Seattle, Wash.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold, 2413 W. Carson St., Pittsburgh 4, Pa.
Milton Roy Co., 1329 E. Mermaid Lane, Philadelphia 18, Pa.
Omega Machine Co., 345 Harris Ave., Providence 1, R. I.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Roots-Connersville Blower Corp., P. O. Box 827, Connersville, Ind.
Simplex Valve & Meter Co., 6742 Upland St., Philadelphia, Pa.
R. W. Sparling, Box 3277, Terminal Annex, Los Angeles, Calif.
Wallace & Tiernan Co., Inc., Belleville 9, N. J.

CHLORINATORS

(See also Hypochlorinators)
Amer. Water Softener Co., Philadelphia 33, Pa.
Builders - Providence, Inc., 345 Harris Ave., Providence 1, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 54, Calif.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Fischer & Porter Co., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Milton Roy Co., 1329 E. Mermaid Lane, Philadelphia 18, Pa.
Omega Machine Co., 345 Harris Ave., Providence 1, R. I.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Wallace & Tiernan Co., Inc., Belleville 9, N. J.

CHLORINE DIOXIDE

(See Sodium Chlorite)

CHLORINE, LIQUID

Diamond Alkali Co., Pittsburgh, Pa.
Hooker Electrochemical Co., 9 Union St., Niagara Falls, N. Y.
John Wiley Jones Co., Caledonia, N. Y.
Mathieson Chem. Corp., 60 E. 42nd St., New York 17, N. Y.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, Fifth Ave. at Bellefield, Pittsburgh 13, Pa.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Day St., New York 7, N. Y.
Solvay Sales Div., 40 Rector St., New York.

CHLORINE CONTROL EQUIPMENT

(See Residual Chlorine Control)

CHUTES, COAL, ETC.

R. D. Cole Mfg. Co., Newnan, Ga.
Hammond Iron Works, Warren, Pa.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

Posey Iron Works, Inc., 540 S. Prince St., Lancaster, Pa.

CLAMPS AND SLEEVES, PIPE

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Dresser Mfg. Co., 251 Fisher Ave., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

CLAMPS, BELL JOINT

Carson-Cadillac Corp., 1221 Pinson St., Birmingham, Ala.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.
Grinnel Co., Inc., 260 W. Exchange St., Providence, R. I.

CLAMPS, PIPE REPAIR

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.

CLARIFIERS SEWAGE AND WATER

American Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., 1610 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., Barry Place, Stamford, Conn.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Jeffrey Mfg. Co., 906 N. 4th St., Columbus 16, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago 6, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

CLAY PIPE

(See Vitrified Clay Pipe and Products)

CLEANING COMPOUNDS

General Chem. Div., 40 Rector St., New York 6, N. Y.
Oakite Products Corp., 73 Thames St., New York 6, N. Y.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Philadelphia Quartz Co., Ledger Bldg., 6th & Chestnut Sts., Philadelphia 6, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Division, Fifth Ave. at Bellefield, Pittsburgh 13, Pa.
Solvay Sales Div., 40 Rector St., New York 6, N. Y.

CLEANING SEWAGE MAINS

(See Sewer Cleaning Equipment and Service)

CLEANING WATER MAINS

Flexible Underground Pipe Cleaning Co., 5059 Venice Blvd., Los Angeles, Calif.
National Water Main Cleaning Co., 50 Church St., New York City.
Phelps Dodge Refining Corp., 40 Wall St., New York 5, N. Y.
Pittsburgh Pipe Cleaner Co., 133 Dahlem St., Pittsburgh 6, Pa.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

CLOROBEN

Cloroben Corp., 115 Exchange Pl., Jersey City, N. J.

COAL & ASH HANDLING MACHINERY

(See Ash & Coal Handling Machinery)

COATINGS, ACID & ALKALI-PROOF

Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Atlas Mineral Products Co., Mertztown, Pa.
Ebony Paint Manufacturing Co., 18th and Agnes Ave., Kansas City 1, Mo.
Haynes Products Co., 4007 Farnam St., Omaha 3, Nebr.
Inertol Co., Inc., 480 Frelinghuysen Ave., Newark 5, N. J.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Philadelphia Quartz Co., Ledger Bldg., 6th & Chestnut Sts., Philadelphia 6, Pa.

COATINGS AND LININGS

(See Bituminous Coatings and Linings)

COCKS (Curb, Meter, Corporation, Etc.)

Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ford Meter Box Co., Wabash, Ind.
Glauber Brass, Inc., Kinsman, Ohio
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Mueller Co., 512 W. Cerro Gordo, Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Av., E. Orange, N. J.
Welsbach Corp., 1500 Walnut St., Philadelphia 2, Pa.

COLLECTORS (Sludge)

(See Sludge Collectors)

COMBUSTION INDICATORS AND RECORDERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Permutit Co., 330 W. 42nd St., New York 18, N.Y.

COMMINUTORS

(See Grinders also)
Chicago Pump Co., 2340 Wolfram St., Chicago, Ill.

COMPARATORS, COLOR

Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
LaMotte Chem. Co., Towson, Baltimore 4, Md.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
W. A. Taylor & Co., 7300 York Road, Baltimore, Md.

COMPOUNDS, SEWER JOINT

Atlas Mineral Prod. Co., Mertztown, Pa.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Hydraulic Development Corp., 59 Church St., New York City.
Robinson Clay Product Co., 45 W. State St., Akron, Ohio.

COMPRESSORS, AIR

Allis-Chalmers Mfg. Co., 1132 S. 70th St., Milwaukee 1, Wis.
Davey Compressor Co., Kent, Ohio
De Laval Steam Turbine Co., Trenton 2, N. J.
Jaeger Machine Co., 716 Dublin Ave., Columbus, Ohio.
Roots-Connersville Blower Corp., P. O. Box 327, Connersville, Ind.
Standard Stoker Co., Erie, Pa.
Yeomans Bros. Co., 1423 N. Dayton St., Chicago 22, Ill.

CONCRETE BREAKERS

Homelite Corp., Riverdale Ave., Port Chester, N. Y.

CONCRETE HARDENER

Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich.
Haynes Products Co., 4007 Farnam St., Omaha 3, Nebr.
Philadelphia Quartz Co., Ledger Bldg., 6th & Chestnut Sts., Philadelphia 6, Pa.

CONCRETE MIXERS

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Jaeger Machine Co., 716 Dublin Ave., Columbus 16, Ohio.

CONCRETE PIPE

Lock-Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Preload Corp., 211 E. 37th St., New York 16, N. Y.

CONDENSERS (Steam)

Allis-Chalmers Mfg. Co., 1132 S. 70th St., Milwaukee 1, Wis.
Blackburn-Smith Mfg. Co., Inc., 95 River St., Hoboken, N. J.
Westinghouse Elec. Corp., Pittsburgh 30, Pa.

CONTRACTORS (Water & Sewage Works)

Cement Gun Co., P. O. Box 424, Allentown, Pa.
Hammond Iron Works, Warren, Pa.
Layne & Bowler, Inc., Box 215, Hollywood Sta., Memphis 8, Tenn.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

CONTROLLERS, FLOW, LEVEL, PRESSURE, TEMPERATURE

B/W Controller Corp., 2206 E. Maple Rd., Birmingham, Mich.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders - Providence, Inc., 345 Harris Ave., Providence 1, R. I.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, Ohio.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Healy-Ruff Co., 783 Hampden Ave., St. Paul, Minn.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Leupold & Stevens Inst., 4445 N. E. Glisan, Portland, Ore.
Lumenite Electronic Co., 407 So. Dearborn, Chicago, Ill.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia, Pa.
R. W. Sparling, Box 3277, Term. Annex, Los Angeles, Calif.

CONVEYORS AND CONVEYING EQUIPMENT

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dracco Corp., 4079 E. 116th St., Cleveland 5, Ohio.
Jeffrey Mfg. Co., 906 N. 4th St., Columbus 16, Ohio.
Link-Belt Mfg. Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Omaha Machine Div., 345 Harris Ave., Providence 1, R. I.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

COPPER, BRASS, BRONZE

American Brass Co., Waterbury, Conn.
Glauber Brass Inc., Kinsman, Ohio.
Hays Mfg. Co., Erie, Pa.

COPPERAS (Sulfate of Iron)

E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.

COPPER SULFATE

General Chemical Div., 40 Rector St., New York 6, N. Y.
Phelps Dodge Refg. Corp., 40 Wall St., New York, N. Y.
E. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.
Tennessee Corp., 619 Grant Bldg., Atlanta, Ga.

COPPER TUBE

American Brass Co., Waterbury, Conn.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

CORROSION SUPPRESSION

Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Electro Rust-Proofing Co., 29 W. Apple St., Dayton, Ohio.
Federal Telephone and Radio Co., Newark 1, N. J.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Wallace & Tiernan, Belleville 9, N. J.

COUPLINGS & CONNECTIONS, PIPE

James P. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Glauber Brass, Inc., Kinsman, Ohio.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.

COUPLINGS, FLEXIBLE

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Jeffrey Mfg. Co., 906 N. 4th St., Columbus 4, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

COVERS, HANDHOLE, MANHOLE, SAMPLING

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Warren Fdry. & Pipe Corp., 11 Broadway, New York, N. Y.

CULVERT CLEANERS

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
W. H. Stewart, 1051 So. Clinton St., Syracuse, N. Y.

CULVERT PIPE

(See Pipe, Culvert)

CURB BOXES

Central Foundry Co., 286 Fourth Ave., New York City.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
H. W. Clark Co., Mattoon, Ill.
Lee Hydraulic Co., Troy, N. Y.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Vernko Products, Inc., Grand Ave. & Skokie Rd., Waukegan, Ill.
Welsbach Corp., 1500 Walnut St., Philadelphia 2, Pa.

CURB STOPS

Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Glauber Brass, Inc., Kinsman, Ohio
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

DECHLORINATING EQUIPMENT AND CHEMICALS

American Water Softener Co., Philadelphia 33, Pa.
Chemical Equipment Co., P. O. Box 3008, Terminal Annex, Los Angeles 12, Calif.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
General Chemical Co., 40 Rector St., New York, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.

Wallace & Tiernan Co., Inc., Belleville 9, N. J.

DE-MINERALIZATION (Water)
Amer. Water Softener Co., Philadelphia 33, Pa.
Chem. Equipment Co., P. O. Box 3066, Term. Annex, Los Angeles 54, Calif.
Derr Co., Barry Place, Stamford, Conn.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Liquid Conditioning Corp., 114 E. Price St., Linden, N. J.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.

DIAPHRAGM, PUMP
(See Pumps, Diaphragm)

DIATOMITE FILTER SEPTUMS
Carborundum Co., Refractories Div., Perth Amboy, N. J.

DIESEL ENGINES
(See Engines, Diesel)

DIFFUSERS—PLATES & TUBES
Carborundum Co., Refractories Div., Perth Amboy, N. J.
Chicago Pump Co., 2249 Wolfram St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equipment, Inc., 518 Hankes Ave., Aurora, Ill.

DIGESTER EQUIPMENT (Sludge)
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chicago Pump Co., 2249 Wolfram St., Chicago 18, Ill.
Derr Co., Barry Place, Stamford, Conn.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Hardinge Co., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

DISTRIBUTORS (Sewage Filter)
American Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Derr Co., Barry Place, Stamford, Conn.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

DRAINS, GUTTER, FLOOR
Ayer-McCarel-Regan Clay Co., Brazil, Ind.
James B. Clow Co., 201 N. Talman Ave., Chicago 80, Ill.
Josam Mfg. Co., 1366 Ontario St., Cleveland 13, Ohio.
Robinson Clay Products Co., 45 W. State St., Akron, Ohio.

DRILLING & BORING EQUIPMENT
Bucyrus-Erie Co., South Milwaukee, Wis.
Hydranger Corp., Ltd., 116 New Montgomery St., San Francisco, Calif.

DRIVES, CHAIN
(See Chains)

DRIVES, RIGHT ANGLE GEAR
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Payne Dean Co., Madison, Conn.

DRIVES, V-BELT
Allis-Chalmers Mfg. Co., 1192 So. 70th St., Milwaukee, Wis.

DRY CHEMICAL FEEDERS
(See Chemical Feeding Equipment)

DRYERS, ROTARY
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Link-Belt Co., 2045 Hunting Park Ave., Philadelphia 40, Pa.

DRYING SYSTEMS (Sludge)
Derr Co., Barry Place, Stamford, Conn.
Gen. Amer. Transp. Co., 10 E. 49th St., New York 17, N. Y.
Morse Boulger Destructor Co., 205 E. 42nd St., New York 17, N.Y.
Nichols Engr. & Res. Corp., 60 Wall Tower, New York, N. Y.

EARTH BORING TOOLS
Hydranger Corp., Ltd., 681 Market St., San Francisco 5, Calif.

EARTH MOVING EQUIPMENT
Bucyrus-Erie Co., South Milwaukee, Wis.
Frank G. Hough Co., 732 Sunnyside Ave., Libertyville, Ill.

EJECTORS, PNEUMATIC or STEAM (For Sewage and Sludge)
Blackburn-Smith Mfg. Co., Inc., 96 River St., Hoboken, N. J.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chicago Pump Co., 2249 Wolfram St., Chicago 18, Ill.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., Seattle, Wash.
Posey Iron Works, Inc., 540 So. Prince St., Lancaster, Pa.
Westinghouse Elect. Corp., Pittsburgh 30, Pa.
Yeomans Bros. Co., 1423 N. Dayton St., Chicago 22, Ill.

ELECTRICAL CONTROL EQUIPMENT
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Automatic Control Co., 1006 University Ave., St. Paul, Minn.
B/W Controller Corp., 2206 E. Maple Rd., Birmingham, Mich.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, Ohio.
General Electric Corp., Schenectady, N. Y.
Healy-Ruff Co., 783 Hampden Ave., St. Paul, Minn.
Lumenite Electronic Co., 407 So. Dearborn St., Chicago, Ill.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

ELECTRICALLY OPERATED GATE VALVES
(See Valves, Motor Operated)

ELEVATING AND CONVEYING EQUIPMENT
(See Conveyors & Conveying Equipment)

ENGINE-GENERATOR UNIT
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Dauer Commercor Co., Kent, Ohio
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Homelite Corp., Riverdale Ave., Port Chester, N. Y.
(Gasoline Engine Driven and Portable)
Westinghouse Electric Corp., Pittsburgh 30, Pa.

ENGINES, DIESEL
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.

ENGINES, DUAL FUEL
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.

ENGINES (Gas & Gasoline)
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.

ENGINES, SLUDGE GAS
Allis Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.

EXPANSION JOINTS—PIPE
(See Joints—Expansion, Pipe)

EXHAUSTERS, AIR
(See Pump, Vacuum)

FANS, EXHAUST AND VENTILATING
Dracco Corp., 4079 E. 116th St., Cleveland 5, O.
Jeffrey Mfg. Co., 906 N. 4th St., Columbus 16, Ohio.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

FEED, CHEMICAL
(See Chemical Feeding Equipment)

FEED WATER FILTERS
Blackburn-Smith Mfr. Co., Inc., 96 River St., Hoboken, N. J.
Chemical Equipment Co., P. O. Box 3066, Terminal Annex, Los Angeles 54, Calif.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.

FEED WATER HEATERS
Blackburn-Smith Mfr. Co., Inc., 96 River St., Hoboken, N. J.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Westinghouse Elect. Corp., Pittsburgh 30, Pa.

FERRIC CHLORIDE
Dow Chemical Co., Midland, Mich.
Jordan Co., 51st St. & Merrimac Ave., Chicago, Ill.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
(Liquid)

FERRIC CHLORIDE FEEDERS
(See Chemical Feed and Proportioning Equipment)

FERRIC SULFATE
Tennessee Corp., 619 Grant Bldg., Atlanta, Ga.

FIBRE PIPE
(See Pipe, Fibre)

FILTER ALUM
Activated Alum Sales Corp., 516 N. Charles St., Baltimore 1, Md.
General Chemical Co., 40 Rector St., New York 6, N. Y.
Penn Salt Mfg. Co., Widener Bldg., Philadelphia 7, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

FILTERING EQUIPMENT
American Water Softener Co., Philadelphia 33, Pa.
American Well Works, 100 N. Broadway, Aurora, Ill.
Blackburn-Smith Mfg. Co., Inc., 96 River St., Hoboken, N. J.
Carborundum Co., Refractories Div., Perth Amboy, N. J.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, N. Y.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
U. S. Hoffman Mach. Corp., 111 Fourth Ave., New York 3, N. Y.
Walker Process Equip. Co., 518 Hankes Ave., Aurora, Ill.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

FILTER PLATES AND TUBES
Carborundum Co., Refractories Div., Perth Amboy, N. J.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.

FILTER RATE CONTROLLERS & GAGES
(See Rate Controllers.)

FILTER SAND & GRAVEL
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

FILTER UNDERDRAINS, SEWAGE
Amer. Water Softener Co., Philadelphia 33, Pa.
American Well Works, 100 N. Broadway, Aurora, Ill.
Carborundum Co., Refractories Div., Perth Amboy, N. J.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Robinson Clay Products Co., 45 W. State St., Akron, Ohio.

FILTER UNDERDRAINS, WATER
Amer. Well Works, 100 N. Broadway, Aurora, Ill.
Ayer-McCarel-Regan Clay Co., Brazil, Ind.
Carborundum Co., Niagara Falls, N. Y.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Nat'l Clay Pipe Mfrs., Inc., 100 N. LaSalle St., Chicago 2, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.

FILTER WASH CONTROL
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Place, Chicago, Ill.

Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.

FITTINGS, PIPE, SOLDER TYPE

American Brass Co., Waterbury, Conn.
Cast Iron Pipe Research Assoc., 122 S. Michigan Ave., Chicago 3, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.
Grinnell Co., Inc., 240 W. Exchange St., Providence 1, R. I.
Hays Mfg. Co., Erie, Pa.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Robinson Clay Products Co., 65 W. State St., Akron, Ohio.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 15, Kan.
Warren Fdry & Pipe Corp., 11 Broadway, New York, N. Y.
R. D. Wood Co., Public Ledger Bldg., Independence Sq., Philadelphia 5, Pa.

FITTINGS, TEES, ELLS, ETC.

Albert Pipe Supply Co., Inc., Berry and N. 13th St., Brooklyn 11, N. Y.
American Cast Iron Pipe Co., Birmingham, Ala.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.
Glauber Brass Inc., Kinsman, Ohio.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., Erie, Pa.
M & H Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

FLASH MIXING EQUIPMENT

(See Mixers & Mixing Equipment)

FLEXIBLE JOINTS

(See Joints, Flexible Pipe.)

FLOATING COVERS (Digester)

Ralph B. Carter, 192 Atlantic St., Hackensack, N. J.
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.

FLOC PRODUCERS

Alhydro, Inc., 516 N. Charles St. Baltimore 1, Md.

FLOCCULATING EQUIPMENT

Amer. Water Softener Co., Philadelphia 33, Pa.
American Well Works, 100 N. Broadway, Aurora, Ill.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., Barry Place, Stamford, Conn.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
P. B. Leopold Co., Inc., 2412 W. Carson St., Pittsburgh 4, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore, Md.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.
Yeomans Bros. Co., 1423 N. Dayton St., Chicago 22, Ill.

FLOOR STANDS

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve Co., Williamsport, Pa.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Iowa Valve Co., Oskaloosa, Iowa.
P. B. Leopold Co., 2413 W. Carson St., Pittsburgh 4, Pa.
M & H Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Rensselaer Valve Co., Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

FLOW METERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Bethlehem Fdry. & Machine Co., Bethlehem, Pa.
Builders - Providence, Inc., 345 Harris Ave., Providence 1, R. I.
Fischer & Porter Co., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 2084, Seattle, Wash.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Leupold & Stevens Inst., 4445 N. E. Glisson, Portland, Ore.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
R. W. Sperling, Box 3277, Term. Annex, Los Angeles, Calif.

FLOW RECORDERS

(See Rate of Flow Recorders)

FLOW REGULATORS

(See Rate of Flow Controllers)

FLOW TUBES

Bethlehem Fdry. & Mach. Co., Bethlehem, Pa.

FLUMES, IRON & STEEL

R. D. Cole Mfg. Co., Newnan, Ga.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

FOOT VALVE WITH STRAINER

(See Valves, Foot)

FORMS & GASKETS FOR PIPE JOINTS

L. A. Weston, Adams, Mass.

FURNACES, MELTING, POURING LADLES, POTS, ETC.

Atlas Mineral Products Co., Mertztown, Pa.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Hydraulic Development Corp., 50 Church St., New York City.
Michael Hayman & Co., Inc., 870 E. Ferry St., Buffalo, N. Y.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.

GAGES (Liquid Level, Pressure Recording)

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders - Providence, Inc., 345 Harris Ave., Providence 1, R. I.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Leupold & Stevens Inst., 4445 N. E. Glisson, Portland, Ore.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia, Pa.
Williams Gauge Co., 1620 Penn. Ave., Pittsburgh 12, Pa.

GARBAGE GRINDERS

(See Grinders)

GAS DIFFUSERS

Carborundum Co., Refractories Div., Perth Amboy, N. J.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.

GAS ENGINES

(See Engines, Gas & Gasoline)

GAS HOLDERS

American Well Works, 180 N. Broadway, Aurora, Ill.
Chicago Bridge & Iron Company, 332 S. Michigan Ave., Chicago, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25, Pa.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.

GAS INDICATORS AND DETECTORS

Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Phipps and Bird, Inc., 321 S. 4th St., Richmond 5, Va.

GATES, SHEAR

Chapman Valve Mfg. Co., 203 Hampshire St., Indian Orchard, Mass.
Iowa Valve Co., Oskaloosa, Iowa.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
M & H Valve & Fittings Co., P. O. Box 909, Anniston, Ala.

GATES, SLUICE

Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Chapman Valve Mfg. Co., 203 Hampshire St., Indian Orchard, Mass.
Filer and Stowell Co., Milwaukee 7, Wis.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 2084, Seattle, Wash.
Iowa Valve Co., Oskaloosa, Iowa.
S. Morgan Smith Co., York, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

GATE VALVE OPERATOR

Darling Valve and Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Payne Dean & Co., Madison, Conn.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

GATE VALVES

(See Valves, Gate)

GEARS, SPEED REDUCING

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
De Laval Steam Turbine Co., Trenton, N. J.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Westinghouse Elec. Corp., Pittsburgh 30, Pa.

GEIGER COUNTERS

The Detectron Co., 5537 Cahuenga Blvd., North Hollywood, Calif.

GENERATORS

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
General Electric Co., Schenectady, N. Y.
Homelite Corp., Riverdale Ave., Port Chester, N. Y.
Westinghouse Elec. Corp., Pittsburgh 30, Pa.

GENERATOR SETS, GAS & DIESEL ENGINES

(See Engine Generating Units)

GOOSENECKS

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Glauber Brass, Inc., Kinsman, Ohio
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

GREASE INTERCEPTORS

Josam Mfg. Co., 1302 Ontario St., Cleveland 13, Ohio.

GREEN SAND (Zeolite)

Amer. Water Softener Co., Philadelphia 33, Pa.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N.Y.
Roberts Filter Mfg. Co., Darby, Pa.
Zeolite Chemical Co., 140 Cedar, New York 6, N. Y.

GRINDERS, GARBAGE & SCREENINGS

Amer. Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., Barry Place, Stamford, Conn.
General Electric Co. (household), Bridgeport, Conn.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Westinghouse Elect. Corp. (household), Pittsburgh, Pa.

GRIT CHAMBER EQUIPMENT & GRIT WASHERS

American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago 18, Ill.
Dorr Co., Barry Place, Stamford, Conn.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.

GROUND KEY STOPS

Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Glauber Brass, Inc., Kinsman, Ohio
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
Welsbach Corp., 1500 Walnut St., Philadelphia 2, Pa.

GUNITING CONTRACTING

Cement Gun Co., P. O. Box 424, Allentown, Pa.

HEATERS, DIGESTER

Dorr Co., Barry Place, Stamford, Conn.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Walker Process Equip. Co., 518 Hankes Ave., Aurora, Ill.

HOSE, STEAM, AIR, WATER, SUCTION

American Brass Co., Waterbury, Conn.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.

HYDRANT PUMPS
(See Pumps, Hydrant)

HYDRANTS (Fire)
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Darling Valve Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Iowa Valve Co., Oskaloosa, Iowa.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., Inc., Box 595, Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N.J.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 15, Kan.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

HYDRAULICALLY OPERATED GATE VALVES
(See Valves, Gate)

HYDROGEN ION EQUIPMENT
(See pH Test Equipment)

HYPO-CHLORINATORS
American Water Softener Co., Philadelphia 24, Pa.
Chemical Equipment Co., P. O. Box 3096, Terminal Annex, Los Angeles 54, Calif.
Everson Filter Service Co., 214 W. Huron St., Chicago, Ill.
Fischer & Porter Co., Hatboro, Pa.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Omega Mach. Co., Inc., 345 Harris Ave., Providence 1, R. I.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Wallace & Tiernan Co., Belleville 9, N. J.

HYPOCHLORITES (High Test)
(See Calcium Hypochlorite)

INCINERATORS
Morse Boulger Destructor Co., 205 E. 42nd St., New York 17, N.Y.
Nichols Engr. & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25, Pa.

INDICATORS, LARGE DIAL, ILLUMINATED
Automatic Control Co., 1006 University Ave., St. Paul, Minn.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders - Providence, Inc., 345 Harris Ave., Providence 1, R. I.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Leupold & Stevens Inst., 4445 N. E. Glisson, Portland, Ore.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
R. W. Sparling, Box 3277, Term. Annex, Los Angeles, Calif.

INSERTING SLEEVES, VALVE
A. P. Smith, 545 N. Arlington Ave., East Orange, N. J.

INSTRUMENTS (Meteorological)
Central Scientific Co., 1700 Irving Park Rd., Chicago 13, Ill.
Leupold & Stevens Inst., 4445 N. E. Glisson, Portland, Ore.
Payne Dean and Co., Madison, Conn.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.
M. C. Stewart, Ashburnham, Mass.
Wallace & Tiernan, Belleville 9, N. J.

INSULATION
Johns-Manville, 22 E. 40th St., New York City.
National Gypsum Co., Buffalo, N. Y.

IRON SULFATE
(See Ferric Sulfate, or Ferrous Sulfate)

JOINTING COMPOUND AND MATERIALS
Atlas Mineral Prod. Co., Mertztown, Pa.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Hydraulic Development Corp., 50 Church St., New York City.
Leadite Co., Philadelphia, Pa.
Michael Hayman & Co., 870 E. Ferry St., Buffalo, N. Y.
Northrop & Co., Inc., Spring Valley, N. Y.
Robinson Clay Products Co., 65 W. State St., Akron, Ohio.

JOINTS, EXPANSION—PIPE
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

JOINTS, MECHANICAL, FLEXIBLE
Amer. Brass Co., Waterbury, Conn.
Carson-Cadillac Corp., 1221 Pinson St., Birmingham, Ala.
Central Foundry Co., 366 Fourth Ave., New York City.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.

JUTE, BRAIDED AND TWISTED
Atlas Mineral Prod. Co., Mertztown, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hydraulic Development Corp., 50 Church St., New York City.
Michael Hayman & Co., Inc., 870 E. Ferry St., Buffalo, N. Y.
Northrop & Co., Inc., Spring Valley, N. Y.

LABORATORY APPARATUS AND REAGENTS
Baker & Adamson Div., 40 Rector St., New York, N. Y.
Central Scientific Co., 1700 Irving Park Rd., Chicago 13, Ill.
Coleman Instruments, Inc., 318 Madison St., Maywood, Ill.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Klett Mfg. Co., 179 E. 87th St., New York 28, N. Y.
LaMotte Chem. Co., Towson 4, Md.
Nat'l Technical Labs., Los Angeles, Calif.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.

LEAD, CAULKING
Colonial Smelting & Ref. Co., Inc., Columbia, Penna.
Michael Hayman & Co., 870 E. Ferry St., Buffalo, N. Y.

LEAK LOCATING INSTRUMENTS
(See Water Leak Locating Instruments)

LIGHTING
General Electric Co., Schenectady, N. Y.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

LIMES
Dow Chemical Co., Midland, Mich.
National Gypsum Co., Buffalo, N. Y.

LIQUID CHLORINE
(See Chlorine, Liquid)

LOCATORS, BOX, PIPE AND VALVE
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Detectron Co., 5437 Cahuenga Blvd., North Hollywood, Calif.
Fischer Research Lab., Inc., 1961 University Ave., Palo Alto, Calif.
Goldak Co., 1543 W. Glenoaks Blvd., Glendale 1, Calif.
E. H. Wachs Co., 1825 Dayton St., Chicago 22, Ill.

MANHOLE FRAMES, COVERS
H. W. Clark Co., Mattoon, Ill.
James B. Clow Co., 201 N. Talman St., Chicago 80, Ill.
Warren Fdry. & Pipe Corp., 11 Broadway, New York, N. Y.

MANOMETERS
Builders - Providence, Inc., 345 Harris Ave., Providence 1, R. I.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

METER ACCESSORIES, BOXES, HOUSING SETTING, ETC.
Art Concrete Works, Pasadena, Calif.
H. W. Clark Co., Mattoon, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Ford Meter Box Co., Wabash, Ind.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R. I.
Iowa Valve Co., Oskaloosa, Iowa.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Meter Specialty Co., 1332 N. 7th St., Memphis, Tenn.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.
R. D. Wood Co., Public Ledger Bldg., Independence Sq., Philadelphia 5, Pa.

METER COUPLINGS & YOKES
H. W. Clark Co., Mattoon, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Badger Meter Mfg. Co., 2357-71 N. 30th St., Milwaukee 10, Wis.
Ford Meter Box Co., Wabash, Ind.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Glauber Brass, Inc., Kinsman, Ohio
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Neptune Meter Co., 50 West 50th St., New York City.
Welsbach Corp., 1500 Walnut St., Philadelphia 2, Pa.

METER REPAIR PARTS
Meter Specialty Co., 1332 N. Seventh St., Memphis, Tenn.

METERS, ELECTRIC
General Electric Co., Schenectady, N. Y.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

METERS, FLOW TUBE
Bethlehem Fdry. & Mach. Co., Bethlehem, Pa.

METERS, GAS
Fischer & Porter Co., Hatboro, Pa.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Roots-Connersville Blower Corp., P. O. Box 327, Connersville, Ind.

METERS, HYDRAULIC TURBINES
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

METER TESTING EQUIPMENT
Badger Meter Mfg. Co., 2357-71 N. 30th St., Milwaukee 10, Wis.
Fischer & Porter Co., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Ford Meter Box Co., Wabash, Ind.
Neptune Meter Co., 50 W. 50th St., New York City.
Worthington-Gamon Meter Co., Newark, N. J.

METERS, VENTURI
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Bethlehem Fdry. & Machine Co., Bethlehem, Pa.
Builders - Providence, Inc., 345 Harris Ave., Providence 1, R. I.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

METERS, WATER & SEWAGE
Badger Meter Mfg. Co., 2357-71 N. 30th St., Milwaukee 10, Wis.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Bethlehem Fdry. & Machine Co., Bethlehem, Pa.
Buffalo Meter Co., 2309 Main St., Buffalo, N. Y.
Builders - Providence, Inc., 345 Harris Ave., Providence 1, R. I.
Fischer & Porter Co., Hatboro, Pa.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Meter Specialty Co., 1332 N. Seventh St., Memphis, Tenn.
Neptune Meter Co., 50 W. 50th St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.
Worthington-Gamon Meter Co., Newark, N. J.

METERS, CLEANING SOLUTION
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, O.
Builders - Providence, Inc., 345 Harris Ave., Providence 1, R. I.
Skasol Corp., Webster Groves, Mo.

MIXERS AND MIXING EQUIPMENT
(Chemical, Water and Sewage)
Amer. Water Softener Co., Philadelphia 32, Pa.
American Well Works, 180 N. Broadway, Aurora, Ill.
Dorr Co., Barry Place, Stamford, Conn.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Infilco, Inc., 325 W. 25th Pl. Chicago 16, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., 2413 W. Carson St., Pittsburgh 4, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 816 N. Charles St., Baltimore 1, Md.

MOTORS, ELECTRIC
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
General Electric Co., Schenectady, N. Y.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

NIPPLES, PIPE
A. M. Byers Co., Pittsburgh, Pa.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Dresser Mfg. Co. Div., Bradford, Pa.

Glauber Brass, Inc., Kinsman, Ohio
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.

NO-OX-ID

Dearborn Chem. Co., 310 S. Michigan Ave., Chicago, Ill.

NOZZLES, FLOW

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders - Providence, Inc., 345 Harris Ave., Providence 1, R. I.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco Inc., 325 W. 25th Pl., Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

NOZZLES, SPRAY

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.
Yeomans Bros. Co., 1423 N. Dayton St., Chicago 22, Ill.

OPERATING TABLES (Filter)

Amer. Water Softener Co., Philadelphia 33, Pa.
Builders - Providence, Inc., 345 Harris Ave., Providence 1, R. I.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Infilco, Inc., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.

ORIFICES

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders - Providence, Inc., 345 Harris Ave., Providence 1, R. I.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

PACKING

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Johns-Manville, 22 E. 40th St., New York City.
Northrop & Co., Inc., Spring Valley, N. Y.

PAINT, ACID RESISTING

Atlas Mineral Prod. Co., Mertztown, Pa.
Ebony Paint Manufacturing Co., 18th and Agnes Ave., Kansas City 1, Mo.
Haynes Products Co., 4007 Farnam St., Omaha 3, Nebr.
Inertol Co., Newark 5, N. J.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

PENSTOCKS

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wisc.
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Hammond Iron Works, Warren, Pa.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25, Pa.
Posey Iron Works, Inc., 540 S. Prince St., Lancaster, Pa.
Santa Fe Tank & Tower Co., 5401 S. Boyle Ave., Los Angeles 58, Calif.

pH TEST EQUIPMENT

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Central Scientific Co., 1700 Irving Park Road, Chicago 13, Ill.
Coleman Instruments, Inc., 318 Madison St., Maywood, Ill.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Beckman Instruments Div., National Technical Laboratories, So. Pasadena, Calif.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
LaMotte Chem. Co., Towson 4, Balto, Md.
The Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Phipps & Bird, Inc., 305 S. 6th St., Richmond 5, Va.
Photovolt Corp., 95 Madison Ave., New York 16, N. Y.
Proportioners, Inc., 345 Harris Ave., Providence 1, R. I.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.
Wallace & Tiernan Co., Inc., Belleville 9, N. J.

PHOTOELECTRIC COLORIMETERS

Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
Photovolt Corp., 95 Madison Ave., New York, N. Y.

PIPE & FITTINGS, SARAN, ETC.

Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Carter Products Corp., Bedford, Ohio

PIPE AND TANK COATINGS

Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Dearborn Chem. Co., 310 S. Michigan Ave., Chicago, Ill.
Ebony Paint Manufacturing Co., 18th and Agnes Ave., Kansas City 1, Mo.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

PIPE, ASBESTOS-CEMENT

Johns-Manville Co., 22 E. 40th St., New York City.
Keasbey & Mattison Co., Ambler, Pa.

PIPE BENDING MACHINES

H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Hays Mfg. Co., Erie, Pa.
Jos. G. Pollard Co., Inc., 141 S. Ashland Pl., Brooklyn 1, N.Y.

PIPE, CAST IRON

Albert Pipe Supply Co., Berry and N. 12th St., Brooklyn 11, N. Y.
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assoc., 122 S. Michigan Ave., Chicago 3, Ill.
Central Foundry Co., 286 4th Ave., New York City.
James B. Clow Co., 201 N. Talman St., Chicago 80, Ill.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R. I.
McWane Cast Iron Pipe Co., P.O. Box 2001, Birmingham, Ala.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
Southwestern Lumber Co., 7487 South Western Ave., Chicago 36, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

PIPE, CEMENT LINED

American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assoc., 122 S. Michigan Ave., Chicago 3, Ill.
Central Foundry Co., 286 Fourth Ave., New York City.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., Public Ledger Bldg., Independence Sq., Philadelphia 5, Pa.

PIPE, CEMENT LINING OF

Centriline Corp., 140 Cedar St., New York City.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

PIPE, CONCRETE, PRESSURE

Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

PIPE, COPPER, BRASS AND BRONZE

American Brass Co., Waterbury, Conn.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

PIPE, CULVERT

Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
General Amer. Transportation Corp., 10 E. 49th St., New York 17, New York.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Nat'l Clay Pipe Mfrs., Inc., 100 N. LaSalle St., Chicago, Ill.
Robinson Clay Product Co., 65 W. State St., Akron, Ohio.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

PIPE CUTTING MACHINES

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Jos. G. Pollard Co., Inc., 141 Ashland Pl., Brooklyn 1, N.Y.
Ridge Tool Co., Elyria, Ohio.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N.J.
E. H. Wachs Co., 1525 Dayton St., Chicago 22, Ill.

PIPE DRILLS

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Jos. G. Pollard Co., Inc., 141 Ashland Pl., Brooklyn 1, N.Y.

PIPE ENAMELS, PROTECTIVE—COAL TAR

Inertol Co., Newark 5, N. J.
Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.

PIPE FITTINGS (See Fittings)

PIPE, HARD RUBBER LINED

American Hard Rubber Co., 11 Mercer St., New York 13, N.Y.
Chemical Equipment Co., P. O. Box 3093, Terminal Annex, Los Angeles 54, Calif.

PIPE JOINT COMPOUNDS (See Jointing Compounds.)

PIPE JOINTS (Mechanical)

Carson-Cadillac Corp., 1231 Pinson St., Birmingham, Ala.
Cast Iron Pipe Research Assoc., 122 S. Michigan Ave., Chicago 3, Ill.
Central Foundry Co., 286 Fourth Ave., New York, N. Y.
Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
L. A. Weston, Adams, Mass.

PIPE JOINT TOOLS

Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.

PIPE LOCATORS

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Detectron Co., 5637 Cahuenga Blvd., North Hollywood, Calif.
Fisher Research Lab., 1961 University Ave., Palo Alto, Calif.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle Wash.
Globe Phone Mfg. Co., Reading, Mass.
Goldak Co., 1543 W. Glenoaks Blvd., Glendale 1, Calif.

PIPE, PLASTIC

Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Carter Products Corp., Bedford, Ohio

PIPE, SEWER

Ayer-McCarel-Regan Clay Co., Brazil, Ind.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Johns-Manville, 22 E. 40th St., New York City.
Keasbey & Mattison Co., Ambler, Pa.
Lock Joint Pipe Co., P. O. Box 269, East Orange, N. J.
Nat'l Clay Pipe Mfrs., 100 N. La Salle St., Chicago, Ill.
Preload Corp., 211 E. 37th St., New York 16, New York.
Robinson Clay Products Co., 65 W. State St., Akron, Ohio.
U. S. Pipe & Foundry Co., Burlington, N. J.

PIPE, STEEL (All Types)

R. D. Cole Mfg. Co., Newnan, Ga.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Posey Iron Works, Inc., 540 S. Prince St., Lancaster, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

PIPE TAPPING MACHINES

Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N.J.

PIPE TEST PLUGS

James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 18, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Richmond Fdry. & Mfg. Co., P. O. Box 5150, Saunders Sta., Richmond, Va.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N.J.

PIPE THAWING, ELECTRICAL, STEAM, FLAME

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.

PIPE TOOLS, (Asbestos, Cement)

Pilot Manufacturing Co., 420 Market St., San Francisco 11, Calif.

PIPE TOOLS (Cutters, Extractors, Threaders, Wrenches, Etc.)

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Pilot Manufacturing Co., 420 Market St., San Francisco 11, Calif.
Jos. G. Pollard Co., Inc., 141 S. Ashland Pl., Brooklyn 1, N.Y.

Ridge Tool Co., 400 Clark St., Elyria, Ohio.
Trimont Mfg. Co., Div. of Aetna Industrial Corp., 85 Armory St., Roxbury 19, (Boston), Mass.

PIPE, VITRIFIED CLAY
(See Vitrified Clay Pipe and Products.)

PIPE, WROUGHT IRON
A. M. Byers Co., Clark Bldg., Pittsburgh, Pa.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Grinnell Co., Inc., 260 N. Exchange St., Providence 1, R. I.
Posey Iron Works, Inc., 540 S. Prince St., Lancaster, Pa.
Sonken-Galamba, 2nd & Riverview, Kansas City 18, Kan.

PITOT TUBES
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Leupold & Stevens Inst., 4445 N.E. Glisson, Portland, Ore.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

PNEUMATIC CONVEYORS FOR WATER AND SEWAGE TREATMENT
Dracco Corp., 4079 E. 116th St., Cleveland 5, Ohio.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

POROUS TUBES AND PLATES
Carborundum Co., Refractories Divn., Perth Amboy, N. J.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

POWER TAKE-OFFS
(Truck Type)
Davey Compressor Co., Kent, Ohio
Payne Dean Co., Madison, Conn.

PRESTRESSED CONCRETE TANKS
Preload Corp., 211 E. 37th St., New York 16, N. Y.

PRESSURE REGULATORS
(See Regulators, Pressure)

PROPORTIONING EQUIPMENT
(See Chemical Feed and Proportioning Equip.)

PUMPING CONTROLS
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Automatic Control Co., 1006 University Ave., St. Paul 4, Minn.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, O.
Builders - Providence, Inc., 845 Harris Ave., Providence 1, R. I.
B/W Controller Corp., 2206 E. Maple Rd., Birmingham, Mich.
Chicago Pump Co., 2349 Wolfram St., Chicago 18, Ill.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, O.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Hesir-Ruff Co., 783 Hampden Ave., St. Paul, Minn.

PUMP PRIMERS
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Milton Roy Co., 1328 E. Mermaid Lane, Philadelphia 18, Pa.
Valve and Primer Corp., 127 N. Dearborn St., Chicago 2, Ill.

PUMPS, ACID-HANDLING
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
De Laval Steam Turbine Co., Trenton 2, N. J.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Peerless Pump Div. Food Machinery and Chemical Corp., 301 W. Ave. 26, Los Angeles 31, Calif.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.

PUMPS, CELLAR DRAINER
(See Pumps, Sump)

PUMPS, CENTRIFUGAL
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
American Well Works, 106 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., 1600 W. Bruce St., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Domestic Engine & Pump Co., Shippensburg, Pa.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3064, Seattle, Wash.
Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio.
Homelite Corp., Riverdale Ave., Port Chester, N. Y.
Jaeger Machine Co., 716 Dublin Ave., Columbus 16, O.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Process Engineers, Inc., 321 Market St., San Francisco 3, Calif.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
Yeomans Brothers Co., 1423 Dayton St., Chicago 22, Ill.

PUMPS, DEEP WELL
American Well Works, 106 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Layne & Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

PUMPS, DIAPHRAGM
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Chemical Equipment Co., P. O. Box 3062, Terminal Annex, Los Angeles 15, Calif.
Domestic Engine & Pump Co., Shippensburg, Pa.
Dorr Co., Barry Place, Stamford, Conn.
Edson Corp., 49 D. St., South Boston, Mass.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Jaeger Machine Co., 716 Dublin Ave., Columbus 16, O.
Marlow Pumps, Inc., 412 Greenwood Ave., Ridgewood, N. J.
Process Engineers, Inc., 321 Market St., San Francisco 3, Calif.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Yeomans Brothers Co., 1423 Dayton St., Chicago 22, Ill.

PUMPS, DRAINAGE (See Pumps, Sewage and Drainage)

PUMPS, HIGH PRESSURE FOR TRUCK MOUNTING
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.

PUMPS, HYDRANT
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Edson Corp., 49 D St., South Boston, Mass.

PUMPS, HYDRAULIC
De Laval Steam Turbine Co., Trenton 2, N. J.
Domestic Engine & Pump Co., Shippensburg, Pa.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Ross Valve Mfg. Co., Inc., Troy, N. Y.

PUMPS, JETTING
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Domestic Engine & Pump Co., Shippensburg, Pa.
Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio.
Jaeger Machine Co., 716 Dublin Ave., Columbus 16, O.

PUMPS, PORTABLE
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., 1600 W. Bruce St., Milwauke 4, Wis.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Domestic Engine & Pump Co., Shippensburg, Pa.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Homelite Corp., Riverdale Ave., Port Chester, N. Y.
Jaeger Machine Co., 716 Dublin Ave., Columbus 16, O.

PUMPS, ROTARY
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Roots-Connersville Blower Corp., P. O. Box 327, Connersville, Ind.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

PUMPS, SELF PRIMING
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Barrett, Haentjens & Co., Hazleton, Pa.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
De Laval Steam Turbine Co., Trenton 2, N. J.
Domestic Engine & Pump Co., Shippensburg, Pa.
Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio.
Homelite Corp., Riverdale Ave., Port Chester, N. Y.
Jaeger Machine Co., 716 Dublin Ave., Columbus 16, O.
Layne & Bowler, Inc., P. O. Box 215 Hollywood Sta., Memphis 8, Tenn.
Marlow Pumps, 412 Greenwood Ave., Ridgewood, N. J.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

PUMPS, SEWAGE AND DRAINAGE
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
American Well Works, 106 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
De Laval Steam Turbine Co., Trenton 2, N. J.
Domestic Engine & Pump Co., Shippensburg, Pa.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3064, Seattle, Wash.
Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio.
Homelite Corp., Riverdale Ave., Port Chester, N. Y.
Jaeger Machine Co., 716 Dublin Ave., Columbus 16, O.
Marlow Pumps, 412 Greenwood Ave., Ridgewood, N. J.
Peerless Pump Division, Food Machinery Corp., 301 W. Avenue 26, Los Angeles 31, Calif.
S. Morgan Smith Co., York, Pa.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

PUMPS, SLUDGE
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
American Well Works, 106 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N. J.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Domestic Engine & Pump Co., Shippensburg, Pa.
Dorr Co., Garry Place, Stamford, Conn.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3064, Seattle, Wash.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Marlow Pumps, 412 Greenwood Ave., Ridgewood, N. J.
Walker Process Equip, Inc., 816 Hanken Ave., Aurora, Ill.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

PUMPS, SUMP (AND CELLAR DRAINER)
American Well Works, 106 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
Barrett, Haentjens & Co., Hazleton, Pa.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton 2, N. J.
Domestic Engine & Pump Co., Shippensburg, Pa.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3064, Seattle, Wash.
Gorman-Rupp Co., 305 Bowman St., Mansfield, Ohio.
Jaeger Machine Co., 716 Dublin Ave., Columbus 16, O.
Peerless Pump Division Food Machinery Corp., 301 West Avenue 26, Los Angeles, Calif.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

PUMPS, TURBINE
American Well Works, 106 N. Broadway, Aurora, Ill.
Aurora Pump Co., 68 Loucks St., Aurora, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Layne & Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.
Peerless Pump Div., Food Machinery Corp., 301 West Avenue, 26, Los Angeles 31, Calif.
S. Morgan Smith Co., York, Pa.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

PUMPS, VACUUM
Allen-Billmyre Div., Lamson Corp., 1061 S. Clinton St., Syracuse.
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Barrett, Haentjens & Co., Hazleton, Pa.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton 2, N. J.
Domestic Engine & Pump Co., Shippensburg, Pa.
Dracco Corp., 4079 E. 116th St., Cleveland 5, O.
Roots-Connersville Blower Corp., P O. Box 327, Connersville, Ind.
U. S. Hoffman Mach. Corp., 111 Fourth Ave., New York 3, N. Y.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

RAIN GAGES
Central Scientific Co., 1700 Irving Park Rd., Chicago 13, Ill.
M. C. Stewart, Ashburnham, Mass.

RATE OF FLOW CONTROLLERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders - Providence, Inc., 845 Harris Ave., Providence 1, R. I.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Fischer & Porter Co., Hatboro, Pa.

Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Pittsburgh Equitable Meter Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

RATE OF FLOW RECORDERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Builders - Providence, Inc., 345 Harris Ave., Providence 1, R. I.
Fischer & Porter Co., Hatboro, Pa.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Leupold & Stevens Inst., 4445 N. E. Glisson, Portland, Ore.
Pittsburgh Equitable Meter Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
R. W. Sparling, Box 3277 Terminal Annex, Los Angeles, Calif.

REAMERS

Ridge Tool Co., Elyria, Ohio.

RECARBONATORS

(See Carbonators)

REFRACTORIES

Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.

REGULATORS, PRESSURE (Water and Gas)

American Radiator Co., Bessemer Bldg., Pittsburgh, Pa.
Automatic Control Co., 1005 University Ave., St. Paul, Minn.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, Ohio.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Golden-Anderson Valve Spec., Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Norwalk Valve Co., 33 Railroad Ave., South Norwalk, Conn.
Ross Valve Mfg. Co., P. O. Box 805, Troy, N. Y.
S. Morgan Smith Co., York, Pa.

RESIDUAL CHLORINE CONTROL APPARATUS

Builders - Providence, Inc., 345 Harris Ave., Providence 1, R. I.
B/W Controller Corp., 2256 E. Maple Rd., Birmingham, Mich.
Chemical Equipment Co., P. O. Box 3098, Term. Annex, Los Angeles 54, Calif.
Fischer & Porter Co., Hatboro, Pa.
Hellige, Inc., 3718 Northern Blvd., Long Island City, N. Y.
LaMotte Chem. Co., Towson 4, Md.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.
Wallace & Tiernan Co., Inc., Belleville 9, N. J.

ROOF COATINGS

Haynes Products Co., 4007 Farnam St., Omaha 3, Nebr.

RUBBER LINED PIPE AND VALVES

American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Chem. Equip. Co., P. O. Box 3098 Term. Annex, Los Angeles 54, Calif.
Darling Valve & Mfg. Co., Williamsport, Pa.

RUBBER PACKING GASKETS

Northrop & Co., Spring Valley, N. Y.

RUST PREVENTION (Tanks, Pipe Lines, Submerged Metal)

Calgon, Inc., Hagan Bldg., Pittsburgh, Pa.
Ebony Paint Mfg. Co., 18th and Agnes Ave., Kansas City 1, Mo.
Electro Rust-Proofing Corp., 1026 Wayne Ave., Dayton 10, Ohio. (Cathodic Protection)
Dearborn Chem. Co., 310 S. Michigan Ave., Chicago, Ill.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Oakite Products, Inc., 73 Thames St., New York 6, N. Y.
Philadelphia Quartz Co., Ledger Bldg., 5th & Chestnut Sts., Philadelphia, Pa.
Wallace & Tiernan, Belleville 9, N. J.

SADDLES, PIPE

Clow & Sons, James B., 201 N. Talman Ave., Chicago 80, Ill.
Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

SAMPLERS AND SAMPLING TABLES

Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.

SAND EXPANSION INDICATORS

Builders - Providence, Inc., 345 Harris Ave., Providence 1, R. I.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

SCALES, SLUDGE CONVEYOR

Builders - Providence, Inc., 345 Harris Ave., Providence 1, R. I.

SCALES, WEIGHING

Fairbanks-Morse Co., 600 S. Michigan Ave., Chicago 5, Ill.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Phipps and Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Wallace & Tiernan, Belleville 9, N. J.

SCREENINGS, DEWATERERS

Gen. Amer. Trans. Corp., 10 E. 49th St., New York 17, N. Y.

SCREENINGS GRINDERS

(See Grinders)

SCREENS, INTAKE

Amer. Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

SCREENS, SAND, GRAVEL AND STONE

Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

SCREENS, SEWAGE

American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., Barry Place, Stamford, Conn.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Walker Process Equip. Co., 518 Hankes Ave., Aurora, Ill.

SCREENS, VIBRATING

Allis-Chalmers Mfg. Co., 1192 S 70th St., Milwaukee 1, Wis.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

SCREENS, WATER WELL

Layne & Bowler, Inc., P.O. Box 215, Hollywood Sta., Memphis 8 Tenn.

SCUM REMOVERS

(See Clarifiers.)

SEGMENT BLOCKS AND PIPE LINER PLATES (Vitrified)

Nat'l Clay Pipe Mfrs. Inc., 100 N. LaSalle St., Chicago 2, Ill.

SEPTIC TANK CLEANERS

Gorman-Rupp Co., 306 Bowman St., Mansfield, Ohio.

SEPTIC TANKS (Vitrified Clay)

Nat'l Clay Pipe Mfrs., Inc., 100 N LaSalle St., Chicago 2, Ill.

SERVICE BOXES

Central Foundry Co., 386 Fourth Ave., New York City.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 18, Ill.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N.J.

SERVICE PIPE

Amer. Brass Co., Waterbury, Conn.
Glauber Brass Inc., Kinsman, Ohio.
Mueller Co., 512 Cerro Gordo St., Decatur 70, Ill.

SEWAGE EJECTORS

(See Ejectors, Pneumatic.)

SEWAGE SAMPLERS

Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.

SEWAGE SLUDGE INCINERATOR

Dorr Co., Barry Place, Stamford, Conn.
Morse Boulger Destructor Co., 205 E. 42nd St., New York 17, N.Y.
Nichols Engineering & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

SEWAGE TREATMENT PROCESSES

The Pic-Chemical Process, 2266 N. Meridian St., Indianapolis, Ind.

SEWER CLEANING EQUIP. AND SERVICE

Bucyrus-Erie Co., South Milwaukee, Wis.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
J. C. Fitzgerald, P.O. Box 289, Coral Gables 34, Fla.
Flexible Sewer-Rod Equpt. Co., 9059 Venice Blvd., Los Angeles, Calif.
National Water Main Cleaning Co., 30 Church St., New York City.
Phelps Dodge Refining Corp., 40 Wall St., New York 5, N.Y.
Pittsburgh Pipe Cleaner Co., 133 Dahlem St., Pittsburgh 6, Pa.
W. H. Stewart, 1051 So. Clinton St., Syracuse, N.Y.
Turbine Sewer Machine Co., 5210 W. State St., Milwaukee, Wis.

SEWER ODOR PREVENTION (See Chlorine.)

Cloroben Corp., Jersey City, N.J.
Pittsburgh Plate Glass Co., Columbia Chem. Div., Fifth Ave., at Bellefield, Pittsburgh 13, Pa.
Welsbach Corp., 1500 Walnut St., Philadelphia 2, Pa.

SEWER PIPE

(See Pipe, Sewer.)

SEWER PIPE JOINTS

Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.

SEWER RODS

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Flexible Sewer-Rod Equpt. Co., 9059 Venice Blvd., Los Angeles, Calif.
W. H. Stewart, 1051 So. Clinton St., Syracuse, N. Y.

SIPHONS (Sewage)

American Well Works, 100 N. Broadway, Aurora, Ill.
Ralph B. Carter Co., 192 Atlantic St., Hackensack, N.J.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.

SLEEVES, PIPE REPAIR

Clow & Sons, James B., 201 N. Talman Ave., Chicago 80, Ill.
Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.
Eddy Valve Co., Waterford, N.Y.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Rensselaer Valve Co., Troy, N.Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
Warren Foundry & Pipe Corp., 11 Broadway, New York City.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

SLEEVES, TAPPING (Valve)

Eddy Valve Co., Waterford, N.Y.
Dresser Mfg. Div., 251 Fisher Ave., Bradford, Pa.
Iowa Valve Co., Oskaloosa, Ia.
Kennedy Valve Mfg. Co., Elmira, N.Y.
M. & H. Valve & Fittings Co., P.O. Box 909, Anniston, Ala.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Rensselaer Valve Co., Troy, N.Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.

SLUDGE COLLECTORS

American Well Works, 100 N. Broadway, Aurora, Ill.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago 18, Ill.
Dorr Co., Barry Place, Stamford, Conn.
H. D. Fowler Co., Inc., 901 Lane St., P.O. Box 3084, Seattle, Wash.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Jeffrey Mfg. Co., 996 N. 4th St., Columbus 16, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Process Engineers, Inc., 821 Market St., San Francisco 3, Calif.
Walker Process Equip., Inc., 518 Hankes Ave., Aurora, Ill.
Yeomans Brothers Co., 1423 N. Dayton St., Chicago 22, Ill.

SLUDGE DISINTEGRATORS

Jeffrey Mfg. Co., Columbus, Ohio.
Roger Foundry & Mach. Co., 158 Pringle St., Kingston, Pa.

SLUDGE EJECTORS

(See Ejectors, Pneumatic.)

SLUDGE ELEVATORS, LIQUID
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Hardinge Corp., York, Pa.
Jeffrey Mfg. Co., 966 N. 4th St., Columbus 16, O.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Walker Process Equip, Inc., 518 Hanks Ave., Aurora, Ill.

SLUDGE GAS ENGINES
(See Engines, Sludge Gas)

SLUDGE PUMPS
(See Pumps, Sludge)

SLUDGE SAMPLERS
Chicago Pump Co., 2249 Wolfram St., Chicago 14, Ill.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.

SNUBBERS
(See Silencers.)

SODA ASH
Diamond Alkali Co., Pittsburgh, Pa.
Mathieson Chem. Corp., 60 East 42nd St., New York 17, N. Y.
Niagara Alkali Co., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Pittsburgh Plate Glass Co., Columbia Chemical Div., Fifth Ave. at Bellefield, Pittsburgh 13, Pa.
R. M. Sergeant Pulp & Chemical Co., Inc., 7 Dey St., New York 7, N. Y.
Solvay Sales Div., 40 Rector St., New York City.

SODIUM BISULPHITE
General Chemical Div., 40 Rector St., New York, N. Y.

SODIUM CHLORITE
Mathieson Chem. Corp., 60 East 42nd St., New York 17, N. Y.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.

SODIUM PHOSPHATES (Glassy)
Calgon, Inc., Hagan Bldg., 223 Fourth Ave., Pittsburgh 30, Pa.

SODIUM SILICATE
Diamond Alkali Co., Pittsburgh, Pa.
General Chemical Div., 40 Rector St., New York 6, N. Y.
Philadelphia Quartz Co., Ledger Bldg., 6th & Chestnut Sts., Philadelphia 6, Pa.
Standard Silicate Division, Diamond Alkali Co., Pittsburgh, Pa.

SOFTENERS
(See Water Softening Equipment)

SPEED REDUCERS, TRANSMISSION
Allis-Chalmers Mfg. Co., 1102 S. 70th St., Milwaukee, Wis.
De Laval Steam Turbine Co., Trenton, N. J.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

SPRINKLING FILTER EQUIP.
Ralph B. Carter, 192 Atlantic St., Hackensack, N. J.
Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Dorr Co., Barry Place, Stamford, Conn.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Pacific Flush Tank Co., 4341 Ravenswood Ave., Chicago 13, Ill.
Walker Process Equip., Inc., 518 Hanks Ave., Aurora, Ill.
Yeomans Bros. Co., 1433 N. Dayton St., Chicago 22, Ill.

SPRINKLING FILTER UNDERDRAINS
(See Filter Underdrains, Sewage.)

STACKS
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.
Posey Iron Works, Inc., 540 S. Prince St., Lancaster, Pa.

STANDPIPES
(See Tanks and Standpipes.)

STANDPIPE AND TANK PRESERVATION
(See Cathodic Protection Process.)

STERILIZING WATER MAINS
(See Water Main Sterilization)

STIRRERS (Laboratory)
Omega Mach. Co., Inc., 545 Harris Ave., Providence 1, R. I.
Phipps & Bird, Inc., 303 S. 6th St., Richmond, Va.
Stuart Corp., 616 N. Charles St., Baltimore 1, Md.

STOKERS
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Ill.
Link-Belt Co., 2410 W. 18th St., Chicago 8, Ill.
Westinghouse Electric & Mfg. Co., Pittsburgh 30, Pa.

STORAGE TANKS
(See Standpipes and Tanks)

STRAINERS, SUCTION
Barrett, Haentjens & Co., Hazleton, Pa.
Blackburn-Smith Mfg. Co., Inc., 96 River St., Hoboken, N. J.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.

SULPHATE OF ALUMINA
(See Filter Alum)

SULPHUR DIOXIDE (Liquid)
Tennessee Corp., 619 Grant Bldg., Atlanta, Ga.

SUPERNATANT LIQUOR
(Selectors and Treaters)
Pacific Flush-Tank Co., 4341 Ravenswood Ave., Chicago 13, Ill.
Walker Process Equip, Inc., 518 Hanks Ave., Aurora, Ill.

SWITCHBOARD & SWITCH GEAR
Allis-Chalmers Mfg. Co., 1102 S. 70th St., Milwaukee 1, Wis.
B/W Controller Corp., 2296 E. Maple Rd., Birmingham, Mich.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, Ohio.
General Electric Co., Schenectady, N. Y.
Westinghouse Electric Mfg. Co., Pittsburgh 30, Pa.

TANK MAINTENANCE & REPAIR
Dixie Tank & Bridge Co., P. O. Box 14, Memphis 1, Tenn.
Hammond Iron Works, Warren, Pa.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Speedeon Elevated Tank Service, 822 N. Court St., Rockford, Ill.

TANKS & PIPES, WOOD
Santa Fe Tank & Tower Co., 5401 S. Boyle Ave., Los Angeles 58, Calif.

TANKS AND STANDPIPES (Steel)
Amer. Car and Foundry Co., 30 Church St., New York 8, N. Y.
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.
R. D. Cole Mfg. Co., Newnan, Ga.
Hammond Iron Works, Warren, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
General American Process Equipment Div., 420 Lexington Ave., New York 17, N. Y.
General Amer. Transportation Corp., 10 E. 40th St., New York 17, N. Y.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25, Pa.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Santa Fe Tank & Tower Co., 5401 S. Boyle Ave., Los Angeles 58, Calif.
Sunken-Calumbo Corp., 2nd & Riverview, Kansas City 18, Kan.

TANKS, RUBBER LINED
Amer. Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Atlas Mineral Products Co., Mertztown, Pa.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Hammond Iron Works, Warren, Pa.
Posey Iron Works, Inc., 540 S. Prince St., Lancaster, Pa.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.

TAPPING MACHINES
Glauber Brass, Inc., Kinsman, Ohio.
Hays Mfg. Co., Erie, Pa.
Mueller Co., 513 W. Cerro Gordo St., Decatur 70, Ill.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.

TASTE & ODOR REMOVAL CHEMICALS
General Chemical Div., 40 Rector St., New York 6, N. Y.
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., Inc., 230 Park Ave., New York 17, N. Y.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Mathieson Chem. Corp., 60 E. 42nd St., New York 17, N. Y.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Pfeiffer Dodge Refg. Corp., 40 Wall St., New York, N. Y.
Pittsburgh Plate Glass Co., Columbia Chemical Div., Fifth Ave. at Bellefield, Pittsburgh 13, Pa.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Stuart Corp., 616 N. Charles St., Baltimore 1, Md.
Welsbach Corp., 1500 Walnut St., Philadelphia 2, Pa.

TESTERS (Water Meter)
Ford Meter Box Co., Wabash, Ind.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Neptune Meter Co., 50 W. 50th St., New York City.
Worthington-Gamon Meter Co., Newark, N. J.

TEST PLUGS (for Pipe)
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Eddy Valve Co., Waterford, N. Y.
Glauber Brass, Inc., Kinsman, Ohio.
Richmond Fdry. & Mfg. Co., P.O. Box 5150, Saunders Sta., Richmond, Va.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., E. Orange, N. J.

THICKENERS (Sludge)
Dorr Co., Barry Place, Stamford, Conn.
General Amer. Transportation Corp., 10 E. 40th St., New York 17, N. Y.
Hardinge Co., Inc., 240 Arch St., York, Pa.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Process Engineers, Inc., 821 Market St., San Francisco 2, Calif.
Walker Process Equip, Inc., 518 Hanks Ave., Aurora, Ill.

TOOL BOXES, PORTABLE
Littleford Bros., Inc., 453 E. Pearl St., Cincinnati 21, Ohio.

TOOLS, PIPE
(See Pipe Tools.)

TOOLS, PNEUMATIC
Jaeger Machine Co., 716 Dublin Ave., Columbus, Ohio.

TRACTORS, BULLDOZERS, Etc.
Bucyrus-Erie Co., South Milwaukee, Wis.
Frank G. Hough Co., 753 Sunnyside Ave., Libertyville, Ill.

TRANSFORMERS, ELECTRIC
Allis-Chalmers Mfg. Co., 1102 S. 70th St., Milwaukee, Wis.
General Electric Co., Schenectady, N. Y.
Westinghouse Electric Corp., Pittsburgh, Pa.

TRAPS, DRIP, FLAME, SEDIMENT
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Josam Mfg. Co., 1302 Ontario St., Cleveland 13, Ohio.
Neptune Meter Co., 50 W. 50th St., New York 20, N. Y.
Pacific Flush Tank Co., 4341 Ravenswood Ave., Chicago 13, Ill.

TRENCHING EQUIPMENT
Bucyrus-Erie Co., South Milwaukee, Wis.
Frank G. Hough Co., 753 Sunnyside Ave., Libertyville, Ill.
Hydrauger Corp., Ltd., 116 New Montgomery St., San Francisco, Calif.

TRICKLING FILTER EQUIPMENT
Chain Belt Co., 1600 W .Bruce St., Milwaukee 4, Wis.
Dorr Co., Barry Place, Stamford, Conn.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Yeomans Bros., 1433 N. Dayton St., Chicago 22, Ill.

TRICKLING FILTER UNDERDRAINS
(See Filter Underdrains)

TRITURATORS
(See also Grinders)
Chain Belt Co., 1866 W. Bruce St., Milwaukee 4, Wis.

TUNNEL LINER PLATES
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.

TURBIDIMETERS
Central Scientific Co., 1700 Irving Park Rd., Chicago 13, Ill.
Hellige, Inc., 3718 Northern Blvd., Long Island City 1, N. Y.
Klett Mfg. Co., 179 E. 87th St., New York 28, N. Y.
LaMotte Chem. Co., Towson 4, Md.
Phipps & Bird, Inc., 303 S. 6th St., Richmond 5, Va.
W. A. Taylor & Co., 7300 York Rd., Baltimore, Md.

TURBINES, HYDRAULIC
Allis-Chalmers Mfg. Co., 1102 S. 70th St., Milwaukee 1, Wis.
De Laval Steam Turbine Co., Trenton, N. J.
S. Morgan Smith Co., York, Pa.

TURBINES, STEAM
Allis-Chalmers Mfg. Co., 1102 S. 70th St., Milwaukee 1, Wis.
De Laval Steam Turbine Co., Trenton, N. J.
Westinghouse Elect. Corp., Pittsburgh 30, Pa.
Worthington Pump & Mach. Corp., Harrison, N. J.

UNIT SUBSTATIONS
Allis-Chalmers Mfg. Co., 1102 S. 70th St., Milwaukee, Wis.
General Electric Co., Schenectady, N. Y.
Westinghouse Electric Corp., Pittsburgh 30, Pa.

VALVE BOXES
Central Foundry Co., 366 Fourth Ave., New York City.
Chapman Valve Mfg., Indian Orchard, Mass.
James B. Clow & Sons, 201-299 N. Talman Ave., Chicago 80, Ill.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Eddy Valve Co., Waterford, N. Y.
Ford Meter Box Co., Wabash, Ind.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R. I.
H. W. Clark Co., Mattoon, Ill.
Iowa Valve Co., Oskaloosa, Ia.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., P. O. Box 980, Anniston, Ala.
Mueller Co., 513 W. Cerro Gordo St., Decatur 70, Ill.

Rensselaer Valve Co., Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
Verako Products, Inc., Grand Ave. & Skokie Rd., Waukegan, Wis.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

VALVE BOX LOCATORS

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Detectron Co., 5457 Cahuenga Blvd., North Hollywood, Calif.
Globe Phone Mfg. Corp., Reading, Mass.
Goldak Co., 1543 W. Glenoaks Blvd., Glendale 1, Calif.

VALVE INSERTING MACHINES

A. P. Smith Mfg. Co., 545 No. Arlington Ave., East Orange, N. J.

VALVE OPERATOR

(See Gate Valve Operator)

VALVES

American Car & Fdry. Co., 30 Church St., New York 8, N. Y.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Darling Valve & Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Co., Keenan Bldg., Pittsburgh 22, Pa.
Iowa Valve Co., Oskaloosa, Ia.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N.J.
S. Morgan Smith Co., York, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
Walsbach Corp., 1500 Walnut St., Philadelphia 2, Pa.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

VALVES, AIR RELEASE

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Darling Valve & Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
Golden, Anderson Valve Co., Keenan Bldg., Pittsburgh 22, Pa.
Iowa Valve Co., Oskaloosa, Ia.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
Rensselaer Valve Co., Troy, N. Y.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Valve and Primer Corp., 127 N. Dearborn St., Chicago 2, Ill.

VALVES, AIR & VACUUM

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, Ohio.
Darling Valve & Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
H. D. Fowler Co., Inc. 901 Lane St., P. O. Box 3084, Seattle, Wash.
Iowa Valve Co., Oskaloosa, Ia.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Nordstrom Valve Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Rensselaer Valve Co., Troy, N.Y.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Valve and Primer Corp., 127 N. Dearborn St., Chicago, Ill.

VALVES, ALTITUDE

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, BACKWATER

Golden-Anderson Valve Co., Keenan Bldg., Pittsburgh 22, Pa.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Josam Mfg. Co., 1202 Ontario St., Cleveland 13, Ohio.

VALVES, BUTTERFLY

Crane Co., 836 S. Mich. Ave., Chicago 5, Ill.
Fischer & Porter Co., Hatboro, Pa.
H. D. Fowler Co., Inc., 901 Lane St., P.O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.

VALVES, CHECK

Amer. Car and Foundry Co., 30 Church St., New York 8, N. Y.
Barrett, Haentjens & Co., Hazleton, Pa.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
Golden-Anderson Valve Co., Keenan Bldg., Pittsburgh 22, Pa.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
Iowa Valve Co., Oskaloosa, Ia.
Josam Mfg. Co., 1788 E. 11th St., Cleveland, Ohio.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., P.O. Box 909, Anniston, Ala.
Mueller Co., 512 W. Cerro Gordo St., Decatur, Ill.
Northrop & Co., Inc., Spring Valley, N. Y.
Norwalk Valve Co., 33 Railroad Ave., South Norwalk, Conn.
Rensselaer Valve Co., Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
S. Morgan Smith Co., York, Pa.
Williams Gauge Co. 1620 Penn Ave., Pittsburgh 12, Pa.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

VALVES, CHLORINE

Amer. Car and Fdy. Co., 30 Church St., New York 8, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Fischer & Porter Co., Hatboro, Pa.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Wallace & Tiernan Co., Inc. Belleville 9, N. J.

VALVES, (Compression)

Glauber Brass, Inc., Kinsman, Ohio

VALVES, CONE

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
Kennedy Valve Mfg. Co., Elmira, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, DIAPHRAGM

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland 10, Ohio.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Fischer & Porter Co., Hatboro, Pa.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
Grinnell Co., Inc., 240 W. Exchange St., Providence 1, R. I.
Norwalk Valve Co., 33 Railroad Ave., South Norwalk, Conn.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.

VALVES, ELECTRICALLY OPERATED

(See Valves, Motor Operated.)

VALVES, EMERGENCY TRIP

Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
Kennedy Valve Mfg. Co., Elmira, N. Y.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.

VALVES, FLAP

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Iowa Valve Co., Oskaloosa, Ia.
Josam Mfg. Co., 1202 Ontario St., Cleveland 13, Ohio.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., P.O. Box 909, Anniston, Ala.
Norwalk Valve Co., 33 Railroad Ave., South Norwalk, Conn.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.

VALVES, FLOAT

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Clark Controller Co., 1146 E. 152nd St., Cleveland 10, Ohio.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Iowa Valve Co., Oskaloosa, Ia.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.
S. Morgan Smith Co., York, Pa.

VALVES, FOOT

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Eddy Valve Co., Waterford, N. Y.
Edson Corp., 49 D St., South Boston, Mass.
Grinnell Co., Inc., 260 W. Exchange St., Providence 1, R. I.
Iowa Valve Co., Oskaloosa, Ia.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
The Williams Gauge Co., 1620 Penn. Ave., Pittsburgh 12, Pa.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.

VALVES, FOUR WAY

American Water Softener Co., Philadelphia 33, Pa.
American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
R-S Products Corp., Wayne Junction, Philadelphia, Pa.
Roberts Filter Mfg. Co., Darby, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

VALVES, GATE

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Darling Valve Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Iowa Valve Co., Oskaloosa, Ia.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Rensselaer Valve Co., Troy, N. Y.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.
R. D. Wood Co., Public Ledger Bldg., Independence Square, Philadelphia, Pa.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.

VALVES, HARD RUBBER LINED

American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.

VALVES, HYDRAULIC CYLINDER OPERATED

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve & Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
Iowa Valve Co., Oskaloosa, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Rensselaer Valve Co., Troy N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
R. S. Products Corp., Wayne Junction, Philadelphia 44, Pa.
A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
S. Morgan Smith Co., York, Pa.
Stuart Corp. 516 N. Charles St., Baltimore 1, Md.
Vogt Brothers Mfg. Co., Louisville, Ky.

VALVES, LUBRICATED PLUG

American Car & Fdy Co., 30 Church St., New York 8, N. Y.
Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Kan.

VALVES, MOTOR OPERATED

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Darling Valve & Mfg. Co., Williamsport, Pa.
Eddy Valve Co., Waterford, N. Y.
H. D. Fowler Co. Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-American Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Hays Mfg. Co., 12th & Liberty Sts., Erie, Pa.
Iowa Valve Co., Oskaloosa, Ia.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
Nordstrom Valve Div., 400 N. Lexington Ave., Pittsburgh, Pa.
Payne Dean and Co., Madison, Conn.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.

A. P. Smith Mfg. Co., 545 N. Arlington Ave., East Orange, N. J.
S. Morgan Smith Co., York, Pa.

VALVES, MUD AND PLUG

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Eddy Valve Co., Waterford, N. Y.
Infilco Inc., 325 W. 25th Pl. Chicago 16, Ill.
Iowa Valve Co., Oskaloosa, Ia.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.
Ludlow Valve Mfg. Co., Troy, N. Y.
Marco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
M. & H. Valve & Fittings Co., P. O. Box 909, Anniston, Ala.
Roberts Filter Mfg. Co., Darby, Pa.

VALVES, PRESSURE REDUCING

Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
R-S Products Corp., Wayne Junction, Phila. 44, Pa.
S. Morgan Smith, York, Pa.

VALVES, RELIEF

American Car & Fdy. Co., 30 Church St., New York 8, N. Y.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
Iowa Valve Co., Oskaloosa, Ia.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.
Neptune Meter Co., 50 West 50th St., N. Y. 20.
Norwalk Valve Co., 33 Railroad Ave., South Norwalk, Conn.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, RUBBER, GLASS AND LEAD LINED

American Hard Rubber Co., 11 Mercer St., New York 13, N. Y.
Grinnell Co., Inc., 260 W. Exchange St., Providence, R. I.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.
S. Morgan Smith, York, Pa.

VALVES, SPECIAL, AUTOMATIC (Including Remote Control.)

Barrett, Haentjens & Co., Hazleton, Pa.
Fischer & Porter Co., Hatboro, Pa.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Golden-Anderson Valve Spec. Co., Keenan Bldg., Pittsburgh 22, Pa.
Iowa Valve Co., Oskaloosa, Ia.
Kennedy Valve Mfg. Co., Elmira, N. Y.
Nordstrom Valve Div., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.
S. Morgan Smith Co., York, Pa.
A. P. Smith Mfg. Co., 500 N. Arlington Ave., E. Orange, N. J.

VALVES, WATER METER SPECIAL

Ford Meter Box Co., Wabash, Ind.
Mueller Co., 512 W. Cerro Gordo St., Decatur 70, Ill.

VARIABLE SPEED TRANSMISSIONS

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.

VENTURI TUBES

American Water Softener Co., Philadelphia 33, Pa.
Bailey Meter Co., 1072 Ivanhoe, Cleveland 10, Ohio.
Builders - Providence, Inc., 345 Harris Ave., Providence 1, R. I.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

VIBRATING SCREENS (Liquid)

Chain Belt Co., 1600 W. Bruce St., Milwaukee 4, Wis.
Link Belt Co., 2045 W. Hunting Park Ave., Philadelphia 40, Pa.

VISES, PIPE

Ridge Tool Co., Elyria, Ohio.
Trimont Mfg. Co., Div. of Aetna Industrial Corp., 55 Armory St., Roxbury 19, (Boston), Mass.

VITRIFIED CLAY PIPE AND PRODUCTS

Ayer-McCarel-Regan Clay Co., Brazil, Ind.
Nat'l Clay Pipe Mfrs., Inc., 100 N. La Salle St., Chicago 2, Ill.

WASTE GAS BURNERS

Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.

WATER ANALYSIS EQUIPMENT AND REAGENTS

(See Laboratory Apparatus and Reagent.)

WATER HAMMER ARRESTERS

H. D. Fowler Co., Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Josam Mfg. Co., 1302 Ontario St., Cleveland 13, Ohio.
Ross Valve Mfg. Co., Box 595, Troy, N. Y.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.
S. Morgan Smith Co., York, Pa.

WATER LEAK LOCATING INSTRUMENTS

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
Fisher Research Lab. Inc., 1961 University Ave., Palo Alto, Calif.
H. D. Fowler Co. Inc., 901 Lane St., P. O. Box 3084, Seattle, Wash.
Globe Phone Mfg. Co., Reading, Mass.
Goldak Co., 1543 W. Glenoaks Blvd. Glendale 1, Calif.

WATER LEVEL CONTROL

Automatic Control Corp., 1005 University Ave., St. Paul 4, Minn.
Builders - Providence, Inc., 345 Harris Ave., Providence 1, R. I.
B/W Controller Corp., 2306 E. Maple Rd., Birmingham, Mich.
Fischer & Porter Co., Hatboro, Pa.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Healy-Ruff Co., 733 Hampden Ave., St. Paul, Minn.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
R-S Products Corp., Wayne Junction, Philadelphia 44, Pa.

WATER LEVEL RECORDERS

Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders - Providence, Inc., 345 Harris Ave., Providence 1, R. I.
Fischer & Porter Co., Hatboro, Pa.
Foxboro Co., Neponset Ave., Foxboro, Mass.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Simplex Valve & Meter Co., 6743 Upland St., Philadelphia 42, Pa.

WATER MAIN CLEANING

Flexible Underground Pipe Cleaning Co., 9059 Venice Blvd., Los Angeles, Calif.
National Water Main Cleaning Co., 50 Church St., New York 7, N. Y.
Pittsburgh Pipe Cleaner Co., 133 Dahlem St., Pittsburgh 6, Pa.
Preload Corp., 211 E. 37th St., New York 16, N. Y.
Stuart Corp, 516 N. Charles St., Baltimore 1, Md.

WATER MAIN PACKING GASKETS

Northrop & Co., Spring Valley, N. Y.

WATER MAIN STERILIZATION (A Service)

Alan A. Wood
1649 N. Broad St., Philadelphia, Pa.
Pitts. Plate Glass Co., Columbia Chem. Div., Fifth Ave. at Bellefield, Pittsburgh 13, Pa.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.

WATERPROOFING PAINTS, COMPOUNDS AND MATERIALS

Ebony Paint Mfg. Co., 18th and Agnes Ave., Kansas City 1, Mo.
Haynes Products Co., 4007 Farnam St., Omaha 2, Nebr.
Inertol Co., Newark 5, N. Y.
Johns-Manville, 22 E. 40th St., New York City.
Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.

WATER SOFTENING CHEMICALS AND COMPOUNDS

(See Individual Chemicals for Water Purification and Softening)

WATER SOFTENING EQUIPMENT

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Amer. Water Softening Co., Philadelphia 33, Pa.
American Well Works, 100 N. Broadway, Aurora, Ill.
Builders - Providence, Inc., 345 Harris Ave., Providence 1, R. I.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 54, Calif.
Dorr Co., Inc., Barry Place, Stamford, Conn.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
General Chem. Div., 40 Rector St., New York 6, N. Y.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
F. B. Leopold Co., Inc., 2413 W. Carson St., Pittsburgh 4, Pa.
Liquid Conditioning Corp., 114 E. Price St., Linden, N. J.
Milton Roy Co., 1329 E. Mermaid Lane, Philadelphia 18, Pa.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Walker Process Equip., Inc., 518 Hanks Ave., Aurora, Ill.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

WATER STABILIZATION (Chemicals for)

Calgon, Inc., 323 4th Ave., Pittsburgh 30, Pa.
General Chem. Div., 40 Rector St., New York 6, N. Y.
Phelps Dodge Refining Corp., 40 Wall St., New York 5, N. Y.

WATER SUPPLY CONTRACTORS

(See Contractors)

WATER TREATMENT FOR SCALE AND CORROSION

Amer. Water Softener Co., Philadelphia 33, Pa.
Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Calgon, Inc., 323 4th Ave., Pittsburgh 30, Pa.
General Chemical Co., 40 Rector St., New York 6, N. Y.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Milton Roy Co., 1329 E. Mermaid Lane, Philadelphia 18, Pa.
Oakite Products, Inc., 72 Thames St., New York 6, N. Y.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Pittsburgh Plate Glass Co., Columbia Chemical Div., Fifth Ave. at Bellefield, Pittsburgh 13, Pa.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.
Stuart Corp., 516 N. Charles St., Baltimore 1, Md.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

WATER TREATMENT PLANTS (Steel)

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee, Wis.
Amer. Water Softener Co., Philadelphia 33, Pa.
Chicago Bridge & Iron Co., 332 S. Michigan Ave., Chicago 4, Ill.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Infilco, Inc., 325 W. 25th Pl., Chicago 16, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Pittsburgh-Des Moines Steel Co., Neville Island, Pittsburgh 25, Pa.
Proportioneers, Inc., 345 Harris Ave., Providence 1, R. I.

WEED BURNERS

W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.

WEED KILLERS

Cloroben Corp., 15 Exchange Pl., Jersey 2, N. J.
W. S. Darley & Co., 2810 Washington Blvd., Chicago 12, Ill.
C. H. Dalge Co., Westport, Conn.
Dow Chemical Co., Midland, Mich.
General Chemical Div., 40 Rector St., New York 6, N. Y.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.
Phelps Dodge Refining Corp., 40 Wall St., New York 5, N. Y.

WELLS, COMPLETE

Layne-Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.

WIND VANES AND INDICATORS

M. C. Stewart, Ashburnham, Mass.

WRAPPING, PIPE
(See Pipe, Wrapping)

WRENCHES, REVERSIBLE RATCHET

Dresser Mfg. Co., 251 Fisher Ave., Bradford, Pa.
Eddy Valve Co., Waterford, N. Y.

WROUGHT IRON (Pipe, Gates, Bars, Etc.)

A. M. Byers Co., Clark Bldg., Pittsburgh, Pa.

ZEOLITE AND ZEOLITE SOFTENERS

Allis-Chalmers Mfg. Co., 1192 S. 70th St., Milwaukee 1, Wis.
Amer. Water Softener Co., Philadelphia 33, Pa.
Chemical Equipment Co., P. O. Box 3098, Terminal Annex, Los Angeles 54, Calif.
Graver Water Conditioning Co., 216 West 14th St., New York 11, N. Y.
Infilco, Inc., 325 W. 25th Place, Chicago 16, Ill.
Lakeside Engr. Corp., 222 W. Adams St., Chicago 6, Ill.
Layne-Bowler, Inc., P. O. Box 215, Hollywood Sta., Memphis 8, Tenn.
Permutit Co., 330 W. 42nd St., New York 18, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Zeolite Chemical Co., 140 Cedar St., New York 6, N. Y.

WATER AND SEWAGE WORKS INFORMATION

Where to Find It

LINN H. ENSLOW
Editor
"Water & Sewage Works"

LIST NO. 1—FOR WATER WORKS MANAGERS AND OPERATORS

[For Small and Moderate Size Systems.]

Books	*Publishers*	*Authors*
American Civil Engineering Handbook—5th Ed. ($9.00)	John Wiley & Sons, New York City	Merriman & Wiggin
Bul. No. 21 (a Handbook on Hydraulics) (F)	National Tube Co., Pittsburgh, Pa.	
Census of Water Treatment Plants	A.W.W.A.	
Chlorine Manual (F)	The Chlorine Institute, New York 17, N.Y.	
Conversion Factors for Engineers (F)	The Dorr Co., New York City	
Copper Sulphate in Control of Micro Organisms (F)	Phelps Dodge Refining Corp., New York City	Hale
Elements of Water Supply Engineering (2nd Ed.) ($4.00)	John Wiley & Sons, New York City	Waterman
Engineering Data in Flow of Fluids in Pipes (F)	Crane Co., Chicago	
Examination of Water—6th Ed. ($3.50)	John Wiley & Sons, New York City	Mason & Buswell
Fire Engine Tests and Fire Stream Tables (F)	National Board of Fire Underwriters, N. Y. C.	
Handbook of Cast Iron Pipe (F)	Cast Iron Pipe Research Assn., Chicago	
Handbook of Fire Protection ($4.50)	D. Van Nostrand Co., New York City	Crosby, Fiske & Forster
Hydraulic Tables—3rd Ed. ($2.50)	John Wiley & Sons, New York City	Williams & Hazen
Lab. Manual—Water and Sewage Analysis, 3rd Ed. ($3.00)	McGraw Hill Co., New York City	Theroux, Eldridge, Mallman
Lefax—Data Sheets for Loose Leaf Note Books	Lefax, Inc., Philadelphia, Pa.	Various
Manual for Water Plant Operators ($6.50)	Chemical Publishing Co., Brooklyn 2, N. Y., c/o State Dept. H.	A. A. Hirsch
Manual for Water Works Operators ($3.00)	Texas Water and Sewage Works Assn., Austin, Tex.	Various
Manual of Recommended Water Sanitation Practice (15c)	U.S. Govt. Printing Office, Washington, D.C.	
Manuals and Specifications of A.W.W.A.	Amer. Water Works Assn.	New York City
Manual of Water Quality and Treatment (2nd Ed.) Manual of Water Works Accounting ($4.00) Procedure for Disinfecting Water Mains ($0.15) Recommended Practice for Distribution System Records (2nd Ed.) ($0.45) Recommended Practice for Repairing and Repainting Elevated Tanks, etc. Standard Specifications for Cold Water Meters (3) ($0.20 each) Standard Specifications for Threads for Underground Service Line Fittings		
Microscopy of Drinking Water (4th Ed. $7.50)	John Wiley & Sons, New York City	Whipple-Fair
pH Control (F)	W. A. Taylor Co., Baltimore, Md.	
Plane Surveying ($5.50)	John Wiley & Sons, New York City	Tracy
Plumber's Handbook ($4.00)	McGraw-Hill Co., New York City	Dibble
Public Water Supplies—4th Ed. ($6.50)	John Wiley & Sons, New York City	Turneaure & Russell
Reference Bibliography for Water and Sewage Works	Gilbert Associates, Inc., Reading, Pa.	
Stand. Meth. of Wtr. and Sewage Anal., 9th Ed. ($4.00)	A. P. H. A. and A. W. W. A., New York City	Various
Taste and Odor Control in Water Purification (F)	Industrial Chem. Sales Div., New York 17, N. Y.	
Technical Bulletins on Chlorination (F)	Wallace & Tiernan Co., Newark, N. J.	Various
The Operation of Water Filtration Plants (F)	N. C. State Dept. Health, Raleigh, N. C.	
Water Purification ($7.00)	McGraw Hill Co., New York City	Ellms
Water Purification Control, 3rd Edition	Williams & Wilkins, Baltimore, Md.	Hopkins
Water Purification for Plant Operators ($2.50)	McGraw Hill Co., New York City	Norcom and Brown
Water Rate Structures in America (F)	Public Service Commission of Wisconsin, Madison, Wis.	
Water Supply Control (nominal charge)	N. Y. State Dept. Health, Albany, N. Y.	
Water Treatment and Purification 2nd Ed. ($2.75)	McGraw Hill Co., New York City	Ryan
Water Works Engineering in Disaster (F)	O.C.D. Pub. No. 2022, Washington, D. C.	McCallum
Water Works Handbook ($7.00)	McGraw Hill Co., New York City	Flynn, Weston & Bogert
Water Supply & Treatment, 3rd Ed. ($0.75)	National Lime Assn., Washington, D. C.	Hoover

(F) Available as Free Publication at this writing.

LIST NO. 2—FOR MANAGERS, CHEMISTS AND OPERATORS OF LARGE WATER WORKS

(In addition to List No. 1)

Books	*Publishers*	*Authors*
Applied Hydraulics ($7.50)	John Wiley & Sons, Inc., New York City	Addison
Bibliography on Water & Sewage Analysis	Ga. Inst. Tech.	Weil, Murray & Reid
Boiler Feedwater Purification ($4.00)	McGraw-Hill Co., New York City	Powell
Business Administration for Engineers ($5.00)	McGraw-Hill Co., New York City	Harding & Canfield
Business Law for Engineers ($4.00)	McGraw-Hill Co., New York City	Allen
Chemistry of Water and Sewage Treatment****	Chemical Catalog Company, New York City****	Buswell
Concrete Engineers' Handbook ($6.00)	McGraw-Hill Co., New York City	Hool & Johnson
Corrosion; Causes and Prevention ($7.00)	John Wiley & Sons, Inc., New York City	Uhlig
Corrosion Handbook ($12.00)	McGraw-Hill Co., New York City	Speller
Data Book on Design for Civil Engineers (3 Vols.)	John Wiley & Sons, Inc., New York City	Elwyn E. Seelye
Deep Well Drilling	The Gulf Publishing Co., Houston, Tex.	Walter H. Jeffery
Design of Dams ($5.00)	McGraw-Hill Book Co., New York City	Hanna and Kennedy
Elements of Hydraulics****	John Wiley & Sons, New York City	Merriman
Elimination of Tastes and Odors in Water ($5.00)	McGraw-Hill Co., New York City	Baylis
Financial Administration of Municipal Utilities ($3.75)	Public Administration Service	Tenner
Fresh Water Biology ($8.00)	John Wiley & Sons, New York City	Ward & Whipple
Fresh Water Algae ($6.00)	McGraw-Hill Co., New York City	Smith
Geomorphology	McGraw-Hill Book Co., Inc., New York City	A. K. Lobeck
Ground Water ($6.00)	McGraw-Hill Book Co., New York City	C. F. Tolman

(*Continued on page* R-14)

LIST NO. 2—FOR MANAGERS, CHEMISTS AND OPERATORS OF LARGE WATER WORKS (Con't.)
(In addition to List No. 1)

Books	*Publishers*	*Authors*
Ground Water, Its Development, Uses & Conservation	Edward E. Johnson, Inc., St. Paul, Minn.	Bennison
Guiding Principles of Public Service Reg. (3 Vols.)	Public Utilities Reports, Inc., Rochester, N. Y.	Spurr
Handbook of Applied Hydraulics ($7.50)	McGraw-Hill Co., New York City	Davis
Hydraulics 5th Ed. ($4.00)	McGraw-Hill Co., New York City	King
Index to Jour. of A. W. W. A.—1881-1933 ($2.00)	Am. Water Wks. Assn., New York City	
"Industrial Water Supplies" (nominal charge)	Ohio Geological Survey, Columbus, Ohio	C. W. Foulk
Laboratory Control of Water Purification ($4.00)	Case, Sheppard, Mann Pub. Co., New York 18, N. Y.	Cox
Mechanical Engineers' Handbook—11th Ed. ($6.00)	John Wiley & Sons, New York City	Kent
pH and Its Practical Application ($3.50)	Williams & Wilkins Co., Baltimore, Md.	LaMotte, Kenny & Reed
Physics of the Earth IX	McGraw-Hill Book Co., Inc., New York City	Oscar E. Meinzer
Plumbing Engineering ($3.50)	Pittman Publishing Co., New York	Cleverdon
Pocket Companion (nominal)	Carnegie-Steel Corp., New York City	
Public Health Engineering—Vol. I ($7.50)	John Wiley & Sons, Inc., New York 16, N. Y.	Phelps
Public Utility Rates****	McGraw-Hill Co., New York City****	Barker
Public Utility Rate Structures ($4.00)	McGraw-Hill Co., New York City	Nash
Pump Handbook	National Press, Millbrae, Calif.	Finch
Rainfall and Runoff ($9.00)	MacMillan Co., New York City	Foster
Standards of Hydraulic Institute—8th Ed. ($3.00)	Hydraulic Institute, New York 6, N. Y.	
Standard Practices for Stationary Diesel Engines ($2.50)	Diesel Engine Mfg. Assn., Chicago, Ill.	
Summary of Census Data on Water Treatment Plants in the United States	Am. Water Works Assn. Reprint	U. S. Pub. Health Service
Textbook of Bacteriology ($8.00)	D. Appleton & Co., New York City	Zinser & Jones
The Hardy Cross Method of Distribution System Design	Univ. of Illinois Engr. Exp. Sta. Bul. No. 286	Hardy Cross
The Quest for Pure Water ($5.00)	Amer. Water Wks. Assn., New York 18, N. Y.	Baker
Theory and Practice of Public Utility Valuation****	McGraw-Hill Co., New York City****	Maltbie
Valve Manual ($2.00)	Mo. Water & Sew. Conf.	Lischer
Water Bacteriology—6th Ed. ($4.50)	John Wiley & Sons, New York 16, N. Y.	Prescott, Winslow & McCrady
Water Borne Typhoid Fever Outbreaks (nominal)	Am. Public Health Bureau	Wolman & Gorman
Water Supply and Sewerage ($5.00)	McGraw-Hill Co., New York City	Steel
Water Supply Engineering (4th Ed. $6.50)	McGraw-Hill Co., New York City	Babbitt & Doland
Water Supply Paper No. 658 (Quality of Waters)	U. S. Geological Survey, Washington, D. C.	Stabler

LIST NO. 3—FOR OPERATORS AND MANAGERS OF SMALL SEWAGE WORKS**

Books	*Publishers*	*Authors*
Chemical Treatment of Sewage (nominal)	Amer. Pub. Health Assn., N. Y. C.	Committee Report
Chlorination in Sewage Treatment****	Amer. Pub. Health Assn., N. Y. C.	Committee Reports
Chlorine Manual (F)	The Chlorine Institute, New York 17, N. Y.	
Lab. Manual of Water and Sewage Anal. 3rd Ed. ($3.00)	McGraw-Hill Co., New York City	Theroux, Eldridge & Mallman
Manual for Sewage Plant Operators ($3.50)	Texas Water & Sewage Wks. Assn., c/o State Dept. of Health	
Manuals of the Federation of Sewage Works Assns.	Champaign, Ill.	
Municipal Sewer Ordinances Occupational Hazards in Operation of Sewage Works Sewage Chlorination Utilization of Sewage Sludge as Fertilizer		
Manual of Sewage Works Operation****	New Jersey Sewage Expt. Sta., New Brunswick, N. J.****	
Operation and Control of Sewage Treatment Plants	New York State Dept. Health	N. Y. State Dept. Health
Principles of Sewage Treatment ($0.50)	National Lime Assn., Washington, D. C.	W. Rudolfs and Staff
Reference Bibliography for Water and Sewage	Gilbert Associates, Inc., Reading, Pa.	
Reprints of Technical Papers on Chlorine in Sewage Treatment (F)	Wallace & Tierman Co., Newark, N. J.	Various
Sewage Treatment ($3.50)	John Wiley & Sons, Inc., New York City	Imhoff and Fair
Sewage Treatment Works ($6.00)	McGraw-Hill Book Co., New York City	Keefer
Sewerage and Sewage Disposal Textbook ($6.00)	McGraw-Hill Co., New York City	Metcalf & Eddy
Sewer Rentals ($1.50)	Am. Public Works Assn., Chicago	Various
Stand. Meth. of Water and Sewage Analysis, 9th Ed. ($4.00)	Amer. Pub. Health Assn., N. Y. C.	A. W. W. A.-A. P. H. A.

***Note*—Sewage works men should examine Lists 1 and 2—also for several (F) publications of value to all alike—for instance, "Conversion Factors for Engineers" and the handbooks.

LIST NO. 4—FOR MANAGERS, CHEMISTS AND OPERATORS OF LARGE SEWAGE WORKS**
(In addition to List No. 3)

Books	*Publishers*	*Authors*
American Sewage Practice Vol. 3, Sewage Treatment ($7.00)	McGraw-Hill Co., New York City	Metcalf & Eddy
Industrial Waste Treatment Practice ($5.00)	McGraw-Hill Co., New York City	Eldridge
Modern Sewage Disposal ($3.50)****	Federation of Sewage Works Assns., New York City	Various
Municipal and Rural Sanitation, 3rd Ed.	McGraw-Hill Book Co., Inc., New York City	Ehlers & Steel
Public Health Engineering—Vol. I ($7.50)	John Wiley & Sons, Inc., New York 16, N. Y.	Phelps
Sewage Trade Waste Treatment	Govt. Printer, Adelaide, Australia	Henry J. N. Hodgson
Sewage Disposal****	John Wiley and Sons, New York City****	Kinnicutt, Winslow & Pratt
Sewerage, 11th Ed.****	John Wiley & Sons, New York City	Folwell
Sewerage and Sewage Treatment—2nd Ed. ($4.00)	Intl. Text Book Co., Scranton, Pa.	Hardenberg
Sewerage and Sewage Treatment—6th Ed. ($6.50)	John Wiley & Sons, New York City	Babbitt
Sewers (25 shillings)	Chapman & Hall, London	Bevan and Rees
Solving Sewage Problems ($6.00)	McGraw-Hill Co., New York City	Fuller & McClintock
Stream Sanitation ($3.50)	John Wiley & Sons, Inc., New York 16, N. Y.	Phelps
The Chemistry of Water and Sewage Treatment****	Chemical Catalog Co., New York****	Buswell
The Hoover Plumbing Code (B. H. 13) (nominal)	U. S. Bureau of Standards	

(F) Available as Free Publication at this writing.
****Out of print. Try National Bibliophile Service, 347 Fifth Ave., N. Y. City.

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M & H 30-inch I.R.B.M. Gate Valve with bevel gears, extended type grease case and 4-inch by-pass.

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For Fire Protection Materials Write for Catalog 40

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HUB ENDS . . . . FLANGED ENDS
UNIVERSAL OR STANDARDIZED
MECHANICAL JOINT

VALVES—AWWA approved iron body, bronze mounted with double disc paralled seat or solid wedge. Nonrising stem, outside screw and yoke . . . hydraulic or motor operated . . . spur or bevelled gear . . . square bottom and low pressure. Also, approved Underwriters and A.F.M. series.

HYDRANTS—Standard A.W.W.A. types, also Underwriters and A.F.M. approved. Dry top, revolving head, easy to lubricate. High efficiency because barrel diameter not reduced and there are no working parts or obstructions in waterway. Special Traffic Model designed to yield under impact and be repaired by renewing breakable bolts and coupling.

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ELECTRIC MOTOR OPERATED VALVES
EXTENSION STEMS
SHEAR GATES
MUD VALVES
FLAP VALVES
SLUDGE SHOES
FLANGE and FLARE FITTINGS
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U. S. STANDARDIZED MECHANICAL JOINT PIPE
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FLANGED PIPE AND FITTINGS
FLEXIBLE JOINT PIPE
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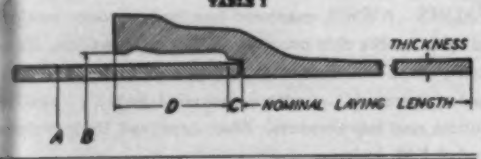
Super deLavaud Pipe with B&S Joints

Super-deLavaud Pipe with bell and spigot joints is available in all sizes from 3" to 24" and in 12-foot and 18-foot lengths. The joint is particularly adaptable for lead, cement, joint compound or rubber ring assembly. The centering ring insures easy alignment and uniform distribution of the jointing material. The process by which this pipe is produced assures concentricity, evenness of metal and freedom from sand or slag inclusions. The bell and spigot joint, made with lead or other jointing materials, shows ample strength to resist pulling apart. If required to meet service conditions, pipe will be furnished with special linings. All Super-de Lavaud Pipe with bell and spigot joints are made to meet Federal Specification WW-P-421. Write for descriptive booklet.

TABLE I



Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length 12-Foot Length: Weight of Pipe Pounds	12-Foot Length: Weight Per Foot Including Bell	18-Foot Length: Weight of Pipe Pounds	18-Foot Length: Weight Per Foot Including Bell
3	350	.38	150	12.7	225	12.4
4	350	.42	198	16.7	297	16.4
6	350	.51	294	24.5	441	24.2
8	350	.60	396	33.0	594	32.7
10	350	.69	504	42.0	756	41.7
12	350	.78	618	51.5	927	51.2
14	250	.84	720	60.0	1080	59.7
16	250	.93	852	71.0	1278	70.7
18	250	1.02	990	82.5	1485	82.2

Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length 12-Foot Length: Weight of Pipe Pounds	12-Foot Length: Weight Per Foot Including Bell	18-Foot Length: Weight of Pipe Pounds	18-Foot Length: Weight Per Foot Including Bell
14	100	.68	840	70.0	1260	69.7
14	150	.75	924	77.0	1386	76.7
14	200	.84	1032	86.0	1548	85.7
14	250	.93	1140	95.0	1710	94.7
14	300	1.02	1260	105.0	1890	104.7
14	350	1.11	1368	114.0	2052	113.7
16	100	.73	960	80.0	1440	79.7
16	150	.82	1080	90.0	1620	89.7
16	200	.93	1224	102.0	1836	101.7
16	250	1.04	1368	114.0	2052	113.7
16	300	1.15	1512	126.0	2268	125.7
16	350	1.26	1656	138.0	2484	137.7
18	100	.78	1080	90.0	1620	89.7
18	150	.88	1218	101.5	1827	101.2
18	200	1.00	1386	115.5	2079	115.2
18	250	1.12	1548	129.0	2322	128.7
18	300	1.24	1716	143.0	2574	142.7
18	350	1.36	1884	157.0	2826	156.7
20	100	.83	1140	95.0	1710	94.7
20	150	.94	1296	108.0	1944	107.7
20	200	1.07	1476	123.0	2214	122.7
20	250	1.20	1656	138.0	2484	137.7
20	300	1.33	1836	153.0	2754	152.7
20	350	1.46	2016	168.0	3024	167.7
24	100	.98	1356	113.0	2034	112.7
24	150	1.12	1548	129.0	2322	128.7
24	200	1.28	1764	147.0	2646	146.7
24	250	1.44	1980	165.0	2970	164.7
24	300	1.60	2208	184.0	3312	183.7
24	350	1.76	2424	202.0	3636	201.7

Threaded Cast Iron Pipe Centrifugally Cast

Super-deLavaud Cast Iron Pipe is now being manufactured in "iron pipe sizes" with threaded joints to meet the demand for a better and more durable pipe. There are two distinct types of service for which Super-deLavaud Cast Iron Pipe may be used: pressure service for water, gas, steam or similar liquids and gases; and drainage service. Pressure pipe is made to meet the requirements of Federal Specifications WW-P-421 and is supplied in three classes: standard, extra-strong and double-extra-strong. Drainage pipe, used for waste, vent and drain work, is a lighter pipe for use in buildings and elsewhere where a tight screw-coupled joint is needed. Drainage pipe is made to meet the requirements of Federal Specifications WW-P-356.

THREADED CAST IRON PRESSURE PIPE

(Made to meet the requirements of Federal Specifications WW-P-421)

Size Inches	Class	Nominal Length, Feet	Outside Diameter, Inches	Nominal Thickness, Inches	Threads per Inch	Weight per foot Pounds
3	Standard	18	3.50	.26	8	11.06
	X-strong	18	3.50	.36	8	13.45
	XX-strong	18	3.50	.46	8	14.21
4	Standard	18	4.50	.26	8	15.34
	X-strong	18	4.50	.36	8	18.91
	XX-strong	18	4.50	.46	8	20.39
5	Standard	18	5.56	.26	8	20.22
	X-strong	18	5.56	.36	8	24.60
	XX-strong	18	5.56	.46	8	26.56
6	Standard	18	6.62	.28	8	24.15
	X-strong	18	6.62	.43	8	30.20
	XX-strong	18	6.62	.61	8	35.76
8	Standard	18	8.62	.32	8	35.65
	X-strong	18	8.62	.50	8	43.39
	XX-strong	18	8.62	.80	8	47.32

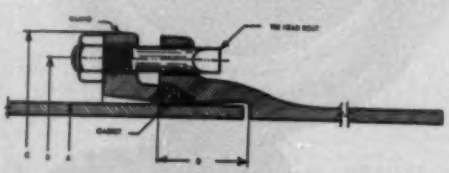
THREADED CAST IRON DRAIN PIPE

For Waste, Vent and Drainage Service

(Made to meet the requirements of Federal Specifications WW-P-356)

Size Inches	Nominal Length Feet	Outside Diameter Inches	Minimum Thickness Inches	Threads per Inch	Weight per Foot Pounds
3	18	3.50	.26	8	9.81
4	18	4.50	.28	8	13.72
5	18	5.56	.30	8	19.06
6	18	6.62	.32	8	24.22
8	18	8.62	.44	8	39.82

U. S. STANDARDIZED MECHANICAL JOINT



We are now prepared to furnish U. S. Standardized Mechanical Joint Pipe and Fittings in sizes from 3" to 24" with parts that are interchangeable with those furnished by other manufacturers of cast iron mechanical joint pipe.

PURCHASING WATERWORKS SUPPLIES AND SERVICES*

HOMER A. HUNTER
Consulting Engineer, Dallas, Texas

WATER works officials responsible for analyzing a set of bids often appear to forget that the law enforces acceptance not of the lowest bid, but of the *lowest and best bid*. The best bid may be the highest in dollars and cents but it may easily be the most adantageous to the city because of other factors involved.

Of course, during the last few years, and particularly during the war, most purchases were probably made wherever the materials could be obtained and too little consideration was given to price and quality. To some extent, availability of equipment and materials is still the deciding factor, but when freedom of choice is possible water works men should exercise considerable caution in buying. Under the law they have a great deal of latitude in the selection of materials, supplies and services to be purchased.

The city manager or council may insist on the purchase of the cheapest article, but, if the water works man knows his business as he should, he will be able to demonstrate that the cheapest buy may not be the best one for the city. He has the responsibility for getting on record a recommendation that is best for the city and he will be derelict in his duty if he takes the easy way out and recommends the lowest price every time. Admittedly it requires some courage to take more difficult position of proving that the more expensive article is best over the years.

Court Decisions

Most city charters require that the *lowest and best bid* be accepted, and the courts have held that it is not necessary to accept the lowest bid but that of the *lowest responsible bidder*. In the case of *O'Brien* v. *Carney* (6 Fed. Supp. 761) the court stated that "responsibility" means more than a pecuniary ability to perform the conditions of the contract; "it includes also judgment, skill, ability, capacity and integrity." In *Interstate Buick* v. *Philadelphia* (164 Pa. 477) it was held that: "'Lowest responsible bidder' means not only pecuniary ability but judgment and skill, and discretion will not be controlled to prevent an award to a higher bidder." In *Clayton* v. *Taylor* (49 Mo. App. 177) the court ruled: "'Lowest responsible bidder' means fitness, responsibility or capacity to perform work, and the determination by council that another was not such will not be reviewed."

Federal Regulations

The United States government now recognizes the difference in quality of various articles and Section 245 of the Navy Procurement Regulations reads, in part:

245.1 *Responsible Bidder.* A responsible bidder is a bidder who: (a) Is qualified and eligible, by law and under this regulation; and (b) is financially responsible, and able successfully to fulfill the contract requirements.

245.2 *Other Factors to Be Considered.* Other factors besides price that may be considered in making an award are the following: (a) Judgment, skill and integrity of a bidder; (b) reputation and experience of a bidder, and prior work of a similar nature done by him; (c) foreseeable costs or delays to the Government resulting from difference in inspection, shipping, location of supplies, etc.; (d) changes made or requested in any of the general or special provisions; (e) restrictions or conditions imposed in the bid; and (f) disadvantages to the Government that might result from making split awards.

Federal Supply Bureau regulations and army procurement regulations also define "responsible" bidders in similar language.

The low-bid procedure used by many city governments in making purchases has placed too great an emphasis on price and has eliminated high quality manufacturers. Often the low bidder proposes to furnish an article difficult to reject under the specifications but lacking intangible elements of top quality which the more able manufacturer can supply. Specifications and even inspection are not complete and adequate quality controls. Specification of design is relatively easy but specification of quality level is almost impossible. For example, proper design and materials may be used in the manufacture of a fire hydrant and it may come up to the standards set by the specification; yet the workmanship and appearance of the hydrant may be well below the desired standard.

Manufacturers' Service Facilities

In making purchases of water work materials and supplies, consideration should also be given to the facilities provided by the manufacturer for servicing the equipment after it is installed. Because many water work items require constant careful operation, periodic servicing is extremely important. If the manufacturer has adequate service facilities, the city may enjoy a considerable saving by not having to keep parts in stock for repairs.

The federal government is placing more and more emphasis on the manufacturer's service facilities. Recently the Veterans' Administration prepared a specification for the purchase of certain X-ray equipment which would eliminate all manufacturers who did not have established repair and maintenance facilities. As a result of complaints by manufacturers to the comptroller general, that official wrote to the Veterans' Administration:

It has been held consistently by the accounting officers that the determination of governmental needs and drafting of specifications and advertisements therefor are primarily matters of administrative responsibility, and when the specifications reflect actual minimum needs of the Government for a particular purpose, they are not unduly restrictive of competition merely because one or more manufacturers may not be able to meet their requirements. . . . In connection therewith, it is understood that, in view of the nature of the equipment involved, the proper maintenance of such equipment by the successful bidder is of prime importance. . . . Accordingly, you are advised that, if it be determined that only bidders having established repair and maintenance facilities can meet the specific requirements of the Veterans' Administration for the particular equipment here involved, this office will not be required to object to the insertion of a clause in the invitation for bids excluding all other bidders.

Another item that might likewise be of considerable importance is the location of spare-parts stocks maintained by the manufacturer. It is often necessary to obtain repair parts quickly for certain apparatus and equipment, and stocks of spare parts close by are very comforting.

Hiring Consultants

The purchasing of special services is also of importance in water works operations and should be taken into account. When there is a need for an engineer or other specialist to analyze some particular construction or operating problem encountered, the utmost care should be exercised in the selection of the proper individual for the job. In developing a new water supply or treatment plant or planning additions to the distribution system or the sanitary sewer system, the engineer with the best training and experience should be employed because he will be able to do the most for the least number of dollars spent. The services of a capable engineer can be purchased for about the same amount as those of one less well trained, and there will be no comparison between the character of work done by the two. The operator must live with the works of the engineer, and the better the engineer, the smaller the operating problems will be. Engineers should be selected because of their experience with the particular type of job to be done. The possession of an engineer's license is not sufficient qualification.

Conclusion

Water works men have a great responsibility in purchasing materials, equipment, supplies and services, and they also have the legal right to purchase the best quality available to them. In considering the purchase of such items, it is entirely legitimate for the purchaser to condition the award of the contract on a number of pertinent factors. For materials, supplies, apparatus and equipment, these factors are:

[1] Reliability of operation of similar or identical equipment;
[2] Proven life of the material or equipment;
[3] Probable cost of repair and upkeep;
[4] Speed with which repairs can be made;
[5] Ease of assembly and disassembly;
[6] Availability of repair and maintenance facilities and parts stocks maintained by the manufacturer;
[7] Advantages of standardization of equipment such as meters, valves and fire hydrants; and
[8] Interchangeability of equipment.

For services, the conditioning factors are:

[1] Experience in doing work similar to that contemplated;
[2] Training of individuals involved;
[3] Responsibility and integrity of individual or company;
[4] Experience in other work closely associated with the particular job to be done; and
[5] Facilities available to the individual or company for doing the work.

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ROSS VALVE MFG. CO., INC.

TROY, NEW YORK

AUTOMATIC CONTROL & PRESSURE REGULATING VALVES

***For* Water Works and Fire Departments**

For accurate service, the automatic control and pressure regulating valves must be right as to type and size for the service required. Our W. R. Type, cast iron, bronze mounted valves in sizes from 4" to 30" are guaranteed for services for which they are designed.

Altitude Valves

Single Acting

Model 40 AWR — semi-throttling hydraulic control to prevent overflow of tank, standpipe or reservoir or to maintain a positive adjustable head for washing and filtering operations. Pilot adjustment range—4 to 30 ft., 30 to 60 ft., 60 to 150 ft.

Model 30 AWR—wide open or closed hydraulic control to prevent overflow of tank, standpipe or reservoir. Pilot adjustment range 4 to 30 ft., 30 to 60 ft., 60 to 150 ft.

Other single acting altitude valves combine back pressure or relief valve and pressure reducing functions.

Double Acting

Model 40 DAWR—to prevent overflow in tank or reservoir and to allow return flow to distribution system when head on tank side is three inches higher than head of distribution system. These valves may be equipped with Remote Hydraulic and Electric Control. When required the return flow can be delayed for a predetermined pressure drop in distribution. Pilot adjustment range—4 to 30 ft., 30 to 60 ft., 60 to 150 ft.

Other double acting altitude valves combine many additional features to prevent dumping of tank, to retain supply on off peak loads and to make available maximum storage for peak load periods. Also a semi-throttling model for gradual closing of feed line and for maintenance of adjusted pressure on the distribution side. Can be equipped with secondary pilot to close valve if break occurs in distribution system.

Surge — Relief — Back-pressure Valves

Model 50 RWR—Single Pilot, Electric and Hydraulic Control—for protection against excessive pressures in distribution systems, supply lines and pump discharge lines. Intaliled in discharge line of deep well pump, provides constant back pressure to prevent overdrafting of the well. Pressure range in pilot—10 to 60 lbs., 20 to 150 lbs., 125 to 250 lbs.

Float Valve or Level Controller

Model 50 FWR—External Pilot Operated—to control main valve so that main stem operates wide open or closed. Pilot valve wastes to atmosphere contents only of operating chamber each time valve stem rises to open position. Maximum inlet pressure, 175 lbs.

Model 40 FWR—External Pilot Operated, Semi-throttling—for gradual closing of valve during last three inches before overflow.

Reducing and Regulating Valves

Model 40 WR—Single Pilot, Hydraulic Control—to maintain constant desired discharge pressure regardless of rate of flow or pressure on upstream side of valve. As a pressure reducing valve, operates to:

1. Control and regulate pressures in gravity and pumping systems.
2. Regulate flow between reservoirs and zones of different pressures.
3. Regulate fire flows between zones of unequal pressures.
4. Regulate pressures in filter wash lines and aerator nozzles.

Valves operate without waste of water to atmosphere and will not induce surge. Can be equipped with dual pilot to permit changing from one pressure to another by mere operation of a three-way cock for systems operating under different day and night pressures. Valves may be supplied with right-angle body. Pressure range outlet—10 to 60 lbs., 20 to 150 lbs., 125 to 250 lbs.

Model 40 WR—Single Pilot, Electric Remote Control—motor driven, geared to pilot adjusting tail screw, made with limit stops to prevent over-travel, and operated by push button switch.

Pressure Reducing and Reverse Flow Valves

Model 50 WR—Single Pilot, Hydraulic Control—for installation at dividing line between two zones to reduce pressure from higher zone, to function as a sleeping valve, discharging into low zone at a time of excessive draft, to permit flow from low to high zone when excessive draft in high zone reduces its pressure below that of the low zone as in case of fire. Pressure range outlet—15 to 60 lbs., 20 to 150 lbs. This valve may be equipped with dual pilot control to permit greater ranges in pilot control and to provide the assurance which goes with duplication and stand-by units.

FIRE DEPARTMENT SPECIALTIES

Portable Fire Hydrant Head for Pressure Reduction—Internal Pilot Operated—for attachment to high pressure main; carried on apparatus to fire, one man can attach (110 lbs. weight) in 18 to 30 seconds, four 2½" hose connections delivering independently from shutoff to full pressure and a fifth connection 2¼" to 3" delivering full pressure.

Hose Valves for Pressure Reduction
Fire Engine Relief Valves

All Ross Valves Repaired in Lines: Internal Packing Replaced Through Top of Valves.

Design of Pressure Tanks for Small Water Systems*

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Dist. San. Engr.
New York State Health Dept., Poughkeepsie, N.Y.

THE hydraulics of hydropneumatic installations was discussed recently in considerable detail by Oscar G. Goldman (1). Pressure tanks for the storage and distribution of water are particularly applicable to small water systems at developments, country clubs, camps, private estates and similar establishments where little fire protection may be desired. Pressure tank water systems have also been designed to serve relatively large communities.

Private dwellings with individual water supplies usually have hydropneumatic systems. The Federal Housing Administration (2) requires in New York State "a pressure tank containing approximately 42 gal. per living unit." The Michigan Dept. of Health (3) suggests, as an approximate rule for the selection of pressure tank sizes for small systems, that the tank have a volume "30 times the pump capacity in gallons per minute." Such a basis must first assure that the source has a yield sufficient to supply the pump selected and meet the water demand. As is apparent, these bases for pressure tank sizes have limited application.

There is need for a quick and simple method of determining the minimum size of water storage pressure tank and pump to provide for a small water system in which the maximum daily consumption does not exceed approximately 50,000 gal. Such a method is developed in this paper.

*Reprinted from JAWWA, Vol. 41, p. 532 by permission.

Theory

Assume that a pressure tank has a total volume equal to Q gallons. The air pressure and volume in the tank, when the temperature is held constant, will follow Boyle's well known law: pv equals a constant. With variation in the absolute pressure from p_1 to p_2 the air volume will vary from v_1 to v_2; hence:

$$p_1v_1 = p_2v_2 \quad \text{.....Eq. (1)}$$

When the pressure tank is just empty, its volume is equal to v_1 and the pressure to p_1; then:

$$Q = v_1 \quad \text{.....Eq. (2)}$$

The water available between p_1 and p_2 is $(Q - v_2)$. This volume is usually made equal to ten or fifteen minutes' storage at the maximum hourly demand and will be called Q_m. Therefore:

$$Q_m = Q - v_2$$
$$v_2 = Q - Q_m \quad \text{.....Eq. (3)}$$

Using the data developed by Goldman, Q_m is equal to the storage at the maximum hourly demand rate, assuming that all the water for a day is used in twelve hours. The maximum hourly rate equals 2.0 times the maximum daily rate, and the maximum daily rate equals 1.5 times the average maximum monthly rate. (For example, if the average maximum monthly water consumption is 6,000 gal., this would correspond to 2,000 gpd., or, if all the water is used within twelve hours, the maximum daily rate would be $1.5 \times 2{,}000 \times \frac{24}{12} = 6{,}000$ gpd. The maximum hourly rate would then be $2 \times 6{,}000 = 12{,}000$ gpd., or 8.33 gpm. The fifteen-minute storage, Q_m, would be $8.33 \times 15 = 125$ gal.)

Substituting Eq. 2 and 3 in Eq. 1:

$$p_1Q = p_2(Q - Q_m)$$

$$Q = \frac{Q_m}{1 - \frac{p_1}{p_2}} \quad \text{.....Eq. (4)}$$

Application

It is therefore possible to compute directly the required volume of a pressure storage tank by substituting in Eq. 4. For practical purposes, p_2 (absolute) can be taken as equal to the required minimum gage pressure at the storage tank in pounds per square inch, plus atmospheric pressure, needed to operate satisfactorily the highest fixture. Atmospheric pressure may be taken as 14.7 psi. and the pressure at the highest fixture as 15 psi. Of course, all head losses that are significant must also be taken into consideration. The value of p_1 (absolute) is usually between 10 and 20 psi. greater than p_2, with the smaller variation being recommended. Since Eq. 4 is based on an empty pressure storage tank, the inlet and outlet pipelines should enter and leave at the bottom. If the water lines enter and leave the tank from the ends or sides, above the bottom, then a minimum water seal is required at all times above these lines and the required pressure tank volume should be computed above this level.

The size of the pump required can be taken at 120-125 per cent of the maximum hourly demand rate in gallons per minute.

Figure 1 has been prepared from Eq. 4 to simplify and expedite the calculations to obtain the required pressure tank and pump size. It is based upon the provision of fifteen minutes' storage at the maximum hourly demand rate and a pump capacity of 125 per cent of this rate in gallons per minute computed as explained above.

For example, say that the maximum water consumption, based on the maximum monthly rate, is equal to 6,000 gpd. The required minimum gage pressure is 40 psi., and the maximum gage pressure is taken as 50 psi. The ration os p_1 to p_2 absolute is:

$$\frac{p_1}{p_2} = \frac{40 + 14.7}{50 + 14.7} = 0.85$$

Find 6,500 gpd. on Fig. 1 and move horizontally to the right to the curve $\frac{p_1}{p_2} = 0.85$ and then down to the pressure tank volume, 2,710 gal. A 3,000-gal. tank should therefore be used. To find the required pump size, move horizontally from 6,500 gal. to the pump capacity curve and then up to 34 gpm. A 35- or 40-gpm. pump should be used, depending upon what is available.

If only ten minutes' storage is desired, take two-thirds of the pressure tank volume indicated by the curve. The curve can be adapted for greater daily water consumptions. For example, if the average maximum daily water consumption is 50,000 gal. and $\frac{p_1}{p_2}$ is equal to 0.80, the minimum pressure

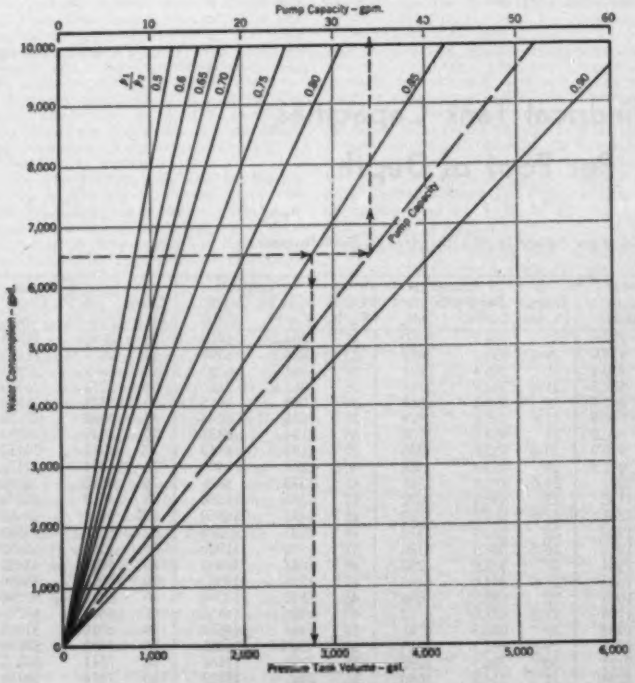

Fig. 1. Tank and Pump Sizes

tank volume required is 15,600 gal. and the pump capacity is 260 gpm.

References

1. Goldman, Oscar G. Hydraulics of Hydropneumatic Installations. Jour. A.W.W.A., 40:144 (Feb. 1948).
2. Requirements for Individual Water Supply and Sewage Disposal Systems. Federal Housing Administration (May 1946).
3. Well Water Supplies. Eng. Bul. 14, Michigan Dept. of Health (March 1940).

Discussion

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Supt., Water Dept.,
San Francisco

The author's paper is a worthy contribution, further stressing the necessity of good design in hydropneumatic installations. Experience shows that the development of this type of installation for domestic water distribution has been sadly neglected. This neglect is largely due to a misunderstanding of the design fundamentals, with a resultant failure of the tank to perform when installed. It should be stressed that the size or volume of the tank is of no value in itself. The usefulness of the tank depends on *the ratio of the volume of air to the volume of water which can be removed for any predetermined pressure drop.*

The author's Eq. 4 is very useful and easily applied. It should be emphasized, however, that the equation assumes an empty tank at the *minimum* pressure condition. In this type of installation it is extremely important that provision be made for a *water seal.* Without an adequate water seal, the variations in air temperature which occur present a real danger of air getting into the distribution system. A properly installed control should also be provided to relieve the excess air due to expansion caused by a rising temperature. Likewise, the finished installation should include means for supplying air to the tank when the temperature falls.

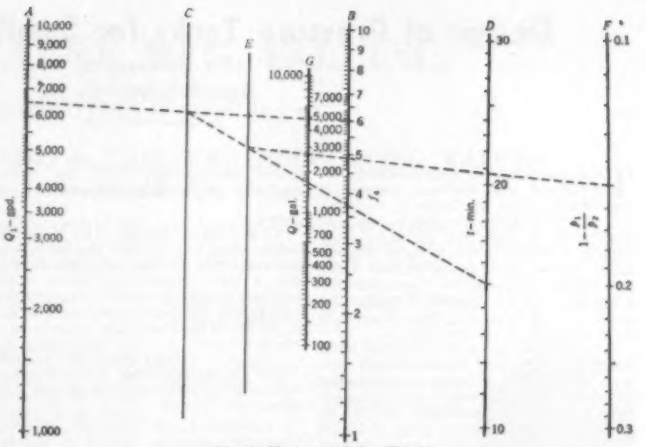

Fig. 2. Nomograph for Eq. 5

Attention is also directed to the fact that the curves proposed by the author are for particular conditions of demand and use, which will differ from place to place. The relationship between thhe average monthly use and the maximum hourly demand should be determined for each locality in question. To do otherwise might cause so great an error that the design of the tank and pump would be a failure.

Instead of a set of curves which might be developed for each special instance, the writer would suggest a generalized nomographic curve applicable to any set of conditions. Let f_1 equal the ratio of hours per day to hours of use; f_2 equal the ratio of maximum daily use to average daily use based on maximum monthly use; f_3 equal the ratio of maximum hourly use to maximum daily use; f_4 equal $f_1 f_2 f_3$; t equal the duration of storage; Q_1 equal the average daily use based on the maximum month; and T equal the number of minutes per day, a constant. Then, based on the author's Eq. 4:

$$Q = \frac{Q_1 f_4 t}{T\left(1 - \frac{p_1}{p_2}\right)} \qquad (5)$$

in which:

$$Q_1 f_4 \frac{t}{T} = Q_m$$

The nomograph in Fig. 2 is for the solution of any problem based on Eq. 5.

Cylindrical Tank Capacities Per Foot of Depth

(The Cubic Foot Figure Is Also the Area in Each Instance)

Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.
1	0.785	5.87	11-6	103.9	777.0	20	314.2	2350	32	804.3	6016	58	2642	19760
1-3	1.227	9.18	9	63.62	475.9	20-6	330.1	2469	33	855.3	6398	60	2827	21150
1-6	1.767	13.22	9-6	70.88	530.2	21	346.4	2591	34	907.9	6792	62	3019	22580
1-9	2.405	17.99	10	78.54	587.5	21-6	363.1	2716	35	962.1	7197	64	3217	24060
2	3.142	23.50	10-6	86.59	647.7	22	380.1	2844	36	1018	7616	66	3421	25590
2-3	3.976	29.74	11	95.03	710.9	22-6	397.6	2974	37	1075	8043	68	3632	27170
2-6	4.909	36.72	12	113.1	846.0	23	415.5	3108	38	1134	8483	70	3848	28790
2-9	5.940	44.43	12-6	122.7	918.0	23-6	433.7	3245	39	1195	8940	72	4072	30450
3	7.069	52.88	13	132.7	992.9	24	452.4	3384	40	1257	9404	74	4301	32170
3-3	8.296	62.06	13-6	143.1	1071	24-6	471.4	3527	41	1320	9876	76	4536	33930
3-6	9.621	71.97	14	153.9	1152	25	490.9	3672	42	1385	10360	78	4778	35740
3-9	11.04	82.62	14-6	165.1	1235	25-6	510.7	3820	43	1452	10860	80	5027	37600
4	12.57	94.00	15	176.7	1322	26	530.9	3972	44	1521	11370	82	5281	39500
4-6	15.90	119.0	15-6	188.7	1412	26-6	551.5	4126	45	1590	11900	84	5542	41450
5	19.63	146.9	16	201.1	1504	27	572.6	4283	46	1662	12430	86	5809	43450
5-6	23.76	177.7	16-6	213.8	1600	27-6	594.0	4443	47	1735	12980	88	6082	45490
6	28.27	211.5	17	227.0	1698	28	615.8	4606	48	1810	13540	90	6362	47590
6-6	33.18	248.2	17-6	240.5	1799	28-6	637.9	4772	49	1886	14110	92	6648	49720
7	38.48	287.9	18	254.5	1904	29	660.5	4941	50	1964	14690	94	6940	51920
7-6	44.18	330.5	18-6	268.8	2011	29-6	683.5	5113	52	2124	15890	96	7238	54140
8	50.27	376.0	19	283.5	2121	30	706.9	5288	54	2290	17130	98	7543	56420
8-6	56.75	424.5	19-6	298.6	2234	31	754.8	5646	56	2463	18420	100	7854	58750

THE PUBLIC AND WATER RATE INCREASES*

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HARRY M. Miller, chairman of the Public Utilities Commission of Ohio, recently delivered an address before the U.S. Independent Telephone Assn. which contained statements regarding telephone companies equally applicable to all water works, whether publicly or privately owned. Miller said in part:

The people . . . are today demanding telephone service of a reasonably high quality. They are merely asking, however, that they be furnished the kind of service which the progressive art of your industry has made possible . . . at a price. Measured by your technical ability, the public demand is altogether fair and reasonable. You have done a splendid job in informing the public what you can do in the way of service, but perhaps not such a convincing job has been done in explaining how it must be done . . . dollars and cents wise. It may be true that the research man in the physical laboratory has done a more thorough job than the manager in the front office. At any rate, our observations convince us that today the public, generally, is not complaining so much about the cost of telephone service as it is about its quantity and quality. In brief, it appears that you have the ways to meet the public demand if you had the means . . .

Another group of companies which have been and are currently providing satisfactory service to their present subscribers are faced with demands from additional subscribers, and with increased usage from present subscribers. Their margins of plant have been exhausted and new capital is required to replace it. Here, again, in many instances, rate structures now in effect were not designed to meet the situation which the demand creates.

In many instances, it is asserted that rates which were designed to meet prewar economic conditions are no longer adequate to meet the situation created by the impact of postwar costs. . . .

These quotations aptly describe the situation in which many water plants now find themselves. Any water works manager whose enterprise is lagging in service or needs new capital to finance the installation of improved or expanding service facilities, and who cannot overcome investor resistance, is faced with the need for increases in rates and has a public relations problem to solve.

That manager's first undertaking should be a complete and careful study of the hard economic facts of his water works and a review of the literature of water works economic theory. The thoughts developed in these studies must next be put to the test of argument with those experienced in water works and general economic practice. Then, with a firm and tested foundation of facts and theories, the manager has the duty of educating and persuading the public. If the preliminary work has been thorough, the results with the public will be satisfactory.

This paper covers only a general presentation of a case for a rate increase.

Cost of Service

Except when water service is rendered largely at the expense of taxpayers as distinguished from water customers, or at the expense of some other group without adequate compensation, water works revenues must be sufficient to meet the complete cost of service. The phrase "cost of service" has often been misunderstood even by experienced operators, and the misunderstanding has led to embarrassment. The first element in the cost of service includes all operating expenses, such as salaries and wages, materials and supplies, coal or purchased power for pumping, and purification and water treatment chemicals. For privately owned plants, operating expenses also include taxes and depreciation. Most municipally owned water plants are not taxed on their property or on their profits although they do pay hidden, or unconsidered, taxes in wage rates, materials and supplies and all other purchases. Many municipal plants, instead of considering depreciation as an operating expense, make provision for the amortization of the water works debt. It is generally believed that both amortization and depreciation expense should not be charged as a cost of service at the same time.

The second element in cost of service, which is often overlooked, is the annual cost of money or capital. The "annual cost of capital" is the amount of money which must be available, after all operating expenses and amortization charges have been met, to enable the enterprise to pay interest charges and have enough left over to sustain a good credit standing and to attract any new capital needed. If this annual cost of capital is not available through operating revenues, the customers are not meeting the cost of service. Probably most water works enterprises are securing enough operating revenue through rates charged customers to enable them to cover their entire operating expenses, but there are many plants which are today not earning enough to meet the full annual cost of capital. As a result, they cannot secure the funds needed for the type and extent of service which the public is demanding. This was the situation referred to by H. M. Miller.

Annual Cost of Capital

The concept of annual cost of capital must not be confused with the cost of capital additions made annually. To illustrate the distinction, a new purification plant might have a cost of $100,000. That would be the cost of the capital addition. In order to be able to borrow the $100,000 for the new construction, it might be necessary to show the prospective investors that the system has earned and would continue to earn $10,000 yearly over and above all operating expenses and other charges and claims. If such a showing were not made, the money for construction could not be secured. This $10,000 would be the annual cost of capital on that portion of the system represented by the new facilities. In calculating the capital or principal amount of bonds which a given amount of operating revenue would justify, investors in special lien or revenue bonds issued by some municipalities insist on a substantial safety margin. This margin is part of the annual cost of capital.

The annual cost of capital cannot remain fixed from year to year but varies with the amount of money invested in the property and with the judgment of investors as to the value of that property. It will also vary with the money market and the ever changing ideas of investment experts concerning prudent managerial and accounting practices.

Failure to realize and to give adequate consideration to the impact of this element of cost of service on the ability of the system to function at full strength is the reason some water works plants are in difficulty today.

With relatively few exceptions the water works enterprises, municipal and private, are operating under customer rates fixed before the last war. Some of them are in the position of being able to supply an expanded demand for service through a plant which was previously overbuilt or with large excess capacity. The growth of business has brought increased revenue without the necessity for additional plant and is more than sufficient to cover increases in operating expenses. Such plants will probably soon reach the stage of development which is now more typical, where all excess capacity has been used up and where demands for service already exceed safe plant yields and the carrying ability of the distribution system.

Since this is believed to be the more usual situation, it is worth looking at the trend of the cost of service and its effect on such a system.

There is no need to labor the record with a recital of detailed costs today compared with those of earlier years. Investigations of such cost trends have been made and published by engineers thoroughly qualified to make the studies and to interpret them. What the present writer wishes to bring out is that an increasing proportion of operating revenue is now being used up in operating expenses, with the consequent lessening of the proportion contributing to the carrying of the annual cost of capital.

A group of water companies in New Jersey in 1934 had an operating ratio—operating expenses divided by operating revenue—of 54.5 per cent. In other words, in that year 45½c out of every dollar of revenue was saved and contributed toward the annual cost of capital. In 1941 the operating ratio was up to 64.5 per cent, and in 1947 it was 71.0. The operating ratio worsened in spite of increased business and some upward rate adjustments, and in 1947 the amount available from revenue for the annual cost of capital was only 29c out of each dollar, compared with 45½c in 1934. For a much larger and widely scattered group of water companies, the operating ratio rose from 50.2 per cent in 1934 to 67.4 in 1947.

Turning now to the annual cost of capital, interest rates on borrowed money are slowly rising. Preferred stocks are not popular and often can be distributed on the market or to institutional investors only if some sinking-fund provision is made. There appears to be a tendency to look critically at the number of times interest or preferred dividends are earned and to demand high rates if the margin of safety is not considered large enough. Investors in equity securities, especially common stocks, in view of the income tax situation and general market conditions, are rather few and insist on attractive

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yields. All of this adds up to a high cost of capital. Moreover, these high-priced dollars do not buy anything like what they used to buy, so that more of them are needed to accomplish a desired end. In prewar days, 1 ft. of 6-in. cement-lined cast-iron pipe cost approximately $1.50 laid; today the price exceeds $3.35. Previously a service line and meter, installed, cost about $35, while today the comparable cost is $66.41.

Most plants at present appear to have reached the saturation point on customers per mile of main. For one large group of water companies, there are 80 customers per mile of main, a figure which has become stationary. This situation is to be expected, considering the common desire to build and live in outlying real estate developments. Whatever the cause, it seems to be the fact that, on the average, a water works system must lay about 70 ft. of pipe for each new customer. Thus, assuming an average pipe size of 6 in., each new customer imposes a capital expenditure for pipe, service and meter only of $300.81. If supply and transmission works are considered in addition to distribution facilities, it is calculated that each customer now costs more than $400. With rates fixed on the basis of pre-war costs and with operating ratios now ranging up to 70 per cent in well managed plants, it becomes clear that each new customer is a burden very difficult to carry.

This statement can be verified by calculation. If the operating ratio of the plant is 70 per cent, each dollar of revenue contributes only 30c to the annual cost of capital, which includes the amount needed to cover not only distribution but also supply facilities. If it is assumed that distribution facilities represent half the cost of the entire system—a condition which is very common—then half of the annual cost of capital must be assigned to the distribution system and half to the supply system. In the present illustration, therefore, only 15c of the revenue dollar is available for the annual cost of capital in distribution facilities. For privately owned plants, as of November 1948, the true annual cost of capital is certainly not less than 6c on each dollar of investment. For municipal plants, the comparable figure is somewhat lower, and it will be assumed as 3c on the dollar. Because of the tax situation, the operating ratio of municipal plants is probably in the neighborhood of 50 per cent.

To find how much investment can be made in pipeline and service connections for each dollar of new revenue, let A equal annual revenue; b equal the operating ratio; C equal the ratio of supply facilities to all facilities; and R equal the annual cost of capital expressed in cents per dollar of investment. The formula will be:

$$X = \frac{(A - Ab)\ C}{R}$$

Substituting 1 for A, 0.70 for b, 0.50 for C and 0.06 for R, X would equal $2.50. According to this formula, then, the enterprise can afford to invest $2.50 in lines and meters for each dollar of new revenue. As most domestic customers today pay on the average only about $15.00 a year, the system can only afford to invest $37.50 for an average customer, while it costs about $300 to attach that customer. For a municipal plant with its lower operating ratio—traceable to the tax differential and the lower annual cost of capital—the application of the formula indicates that such a plant could invest $8.33 in distribution facilities for each dollar of new revenue, or a total of about $125 for a new domestic customer paying $15.00 a year for service. Ignoring the element of annual cost of capital on supply facilities and calculating the amount of revenue remaining available for annual cost of capital after income taxes, private plants could invest $75 in distribution facilities for the average domestic customer. If supply works are ignored in a study of a municipal system, approximately $16.00 per dollar of new revenue would be the proper investment in distribution facilities, or about $250 per average new customer. Thus, it seems almost any method of calculation shows that each new domestic customer requires more investment in distribution facilities than is justified by the existing rates. This is an undesirable situation from the standpoint of the public.

Conclusion

At the very time when the cost of service is advancing, the customers and the public are eager for improved and extended service. The population is growing, but it is not tending to build up in the older sections of communities. As business moves in or blight strikes a neghborhood, the established trend is for movement into outlying newly developed territory. This entails, for the water works, more operating expense, more capital investment at peak unit costs and a greatly expanded annual cost of capital. There is a demand for more uniform and constant quantities and pressures, requiring enlarged distribution facilities and often distribution storage. There is a growing demand for softened water. The per capita water pumpage is rising in well maintained and operated plants, which means that more plants tend to use up their available capacity and come to a realization of the need for new supply works. All this again adds up to an increased cost of service which the public must be brought to understand.

More and better service is a public demand. Water works technicians know how to design and operate the plants which will put completely adequate amounts of good-quality water into the system and deliver it to the consumers. The only drawback is the lack of money. It cannot usually be secured at existing rates because the present cost of service is completely out of line with revenues based on cost figures which are of antiquarian interest and nothing more.

The American people—the water customers—are fair-minded and want to pay their own way. They are capable of understanding these problems and of realizing how their interests harmonize with those of the water systems. All that is needed is a patient educational program carried on by water works men who understand and can explain their own business and its difficulties. When such men step forward, become vocal and evangelize first one or two leaders and then ever widening groups, the public relations aspect of water rate increases will be most pleasant.

INSURANCE PROTECTION FOR MUNICIPAL WATER DEPARTMENTS*

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Types of Insurance Protection

Charles G. Bourgin

IN the construction, operation, maintenance and repair of any water system, perhaps the most common causes of property damage and bodily injury arise from water system construction and water main leaks causing undermining.

Attitudes of Operators

Since the presentation of a previous paper by the author on this subject (1), many inquiries have been received for information on experiences with insurance coverage for this type of damage. From the character of these inquiries, the author was impressed by the widely divergent opinions and attitudes entertained by the operators of many publicly owned water systems toward acknowledging liability not only for damage caused by leaks but for damage resulting from general water works construction. These opinions and attitudes divide the operators into four general classifications:

1. *Operators who have never given any thought to insurance protection or who are totally unaware that such protection is available.* The dangers involved in this "head-in-the-sand" way of thinking—or, more accurately, lack of thinking—are self-evident in this day and age of insurance policies and lawsuits, and require no further discussion.

2. *Operators who entertain the fallacious opinion that a publicly owned water system is a governmental function and, as such, is immune from suit, thus eliminating the need for insurance protection.* It is a well established fact that municipal operation of a water system is not a governmental function like the operation of a police or fire department, but is strictly a proprietary or business function whether or not it operates at a profit. The general legal opinion throughout the nation is that, when a municipality engages in a proprietary enterprise, it makes itself liable to the same extent as any private corporation. In other words, when negligence appears, legal liability follows with resultant exposure to damage suits whether the proprietary operation is publicly or privately conducted.

3. *Operators who have given consideration to insurance protection but who have decided for one reason or another not to carry it.* In general, these men have weighed the risks and have decided that it is more economical not to carry the protection. They feel that the total of all damage claims which may have to be paid over a period of years would be materially less than the cost of insurance premiums over the same period. Some of these operators actually set up a reserve or self-insurance fund, deposits in which are based on estimated premiums for public liability and property damage insurance for their class and size of operation. These deposits continue to be made yearly until the fund has reached an amount sufficient to provide a reasonable degree of security. In the event of a loss, systematic deposits to the fund are resumed until it again reaches the agreed-upon safe level. Other water works pay small damage claims from operations budgets and draw on surplus or reserve funds to meet the larger claims.

Many efficient operators in this class use the best of accepted water works practices in all phases of construction, operation, maintenance and repair. They thus depend upon being able to produce good records, render prompt action in emergencies and display other evidences of good management, so that it becomes extremely difficult for a claimant to prove negligence. Many notable cases are a matter of record in which claims were not allowed by the courts because the water utility, by proving that it consistently operated in a safe and efficient manner, made it difficult, if not impossible, for the claimant to prove negligence. There are also a few operators in this class who rely solely on the influence of municipal ownership to make it hard or awkward for a claimant to prove negligence regardless of the validity of the claim.

Everyone is familiar with the attitude of many insurance companies toward the ready payment of small claims, whether valid or not, chiefly because of their nuisance value. The reverse attitude, however, is generally true of all self-insured operators who display great resistance to the payment of any claim, large or small, which may often work a severe hardship on an honest claimant.

In the author's opinion, although self-insurance programs have real merit—particularly for the larger water utilities, whose insurance premiums would run high for complete public liability and property damage coverage—there is a limit to the size of a claim beyond which self-insurance does not offer adequate protection. It is believed that these operators would do well to carry some form of catastrophe or excessive-loss coverage, which may be obtained at a materially lower premium than that for the same top limits for complete coverage.

4. *Operators who carry public liability and property damage insurance protection in one form or another.* The operators in this class fall into two general groups: [1] those who carry full insurance protection for all claims, large and small; and [2] those who self-insure up to certain limits, usually $5,000-$10,000 aggregate, and then carry excessive-loss insurance to cover the larger claims. Upper limits for both complete coverage and excessive-loss coverage for public liability generally range between $50,000-$200,000 for each person and $100,000-$500,000 aggregate, while those for property damage generally range between $50,000-$100,000 for a single accident and $100,000-$200,000 aggregate.

Types of Coverage

Policies providing these coverages are called contractors' or manufacturers' liability policies and are usually comprehensive in scope—that is, they cover all public liability and property damage risks such as are found in every phase of water works construction, operation, maintenance and repair (including special rates for masonry and concrete construction, carpentry, electrical wiring, plumbing, painting and decorating, if desired). Premiums are computed on the size of classified yearly payrolls. Occasionally, however, when protection against claims arising from water quality is desired as an added feature, premiums for this coverage are based on the quantity of water supplied yearly to the system. This type of coverage, known as manufacturers' products liability insurance, is rarely offered without the addition of the more desirable (to the insurance company) public liability and property damage business. In determining the advance premium, estimates of the coming year's payroll or amount of water to be supplied to the system are made, based on the previous year's experience. These estimates are corrected at the end of the year by payroll audit or examination of water supply records, and the premium is readjusted for final payment or rebate. Premium rates are generally based on the previous five-year experience record of the utility to be insured. When catastrophe or excessive-loss coverage is carried, year-end rebates as high as 15 per cent are enjoyed if no claims have occurred. From these facts, it may be noted that rates are affected by actual claims experience records and that the cost of identical coverage varies with the size of the payroll or quantity of water supplied to the system, depending upon which method of premium computation is used.

Illustrative Cases

The following cases illustrate two ways in which the damage claims against a publicly owned water utility carrying contractors' liability insurance were settled. Further examples may be found in a previously published paper (1) already cited.

Case 1. *Damage to other than municipal property, involving bodily injury resulting from a main break.* A large pipe fracture occurred about noon in a 12-in. main under 110-psi pressure. This main, located in the heart of the business district, had been laid parallel to the curb and under the center of a 10-ft. wide sidewalk running between the curb and the building walls. Extensive damage was done to the sidewalk and the contents of several basements but none to the municipal pavement. A woman was drenched and slightly injured when the break occurred. All claims were covered by contractors' liability insurance, including those for the injury to the woman and the damage to her clothing.

Case 2. *Property damage involving bodily injury as a result of construction, but not the fault of the utility.* A 20-in. main was being installed under a sidewalk around both sides of a corner property. The property consisted of two lots completely grassed over except for the area occupied by a residence which was located on the lot adjacent to the corner lot. The entire property was surrounded by a barberry hedge about 3 ft. high. The open trench, containing newly laid pipe, completely surrounded the entire street frontage of this property. Sidewalk approaches had been thoroughly barricaded, excavated material 5 ft. high lined the curb and the work was more than amply lighted, as later

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agreed on by all concerned. Access to a post-mounted corner mailbox had been provided by a well lighted bridge equipped with guard rails. It remained however, for a neighbor up the street to enter the corner lot via backyards, cross the lawn on private property and leap the barberry hedge near the mailbox as he had done many times before when mailing a letter late at night. Too late he discovered, upon striking the pipe and trench side approximately 6 ft. down, that the sidewalk had been removed. Although acknowledging his error in this rather unorthodox and entirely illegal approach to the mailbox, he registered a claim for back injuries and clothing damage. The insurance company paid both the public liability and property damage claims, even though the fault lay entirely with the claimant. The total claim was not particularly large but probably represented a nuisance value to the insurance company.

Conclusion

Because, in the opinion of the courts, there is no material difference between public and private ownership of a water utility when responsibility for public liability and property damage claims is concerned, every water utility should carry some form of contractors' liability insurance to protect itself from serious losses arising from these claims. The larger utilities perhaps do well at least to carry catastrophe or excessive-loss coverage in conjunction with budgetary provisions for self-insurance coverage for the smaller claims; the smaller utilities might better carry complete coverage. The choice between excessive-loss coverage and complete coverage must be determined from a study of the size of the premium (based on payroll or quantity of water supplied, whichever method is selected), as well as a review of the claims experience record of the particular utility in question. It is also to be noted that operating in a negligent manner is expensive, even though adequate public liability and property damage insurance is carried, since premium rates are based on experience records.

Nuisance Claims

Elmer C. Schwier

This paper will discuss insurance protection against so-called "nuisance" claims, particularly injuries which involve curb boxes, meter pits, valve boxes and fire hydrants.

Any concern which must deal with the general public, such as a department store or theater, is subject to claims for injuries received on company property. This liability also applies to public utilities, in their general offices, in plants where the public is permitted to enter and in the large number of other items of property either owned or maintained by the utility and located over the entire area served.

In Indianapolis, Ind., the water company does not own service lines or curb boxes, but an agreement was made between the company and the Public Service Commission of Indiana in 1930 to the effect that the company would be responsible for the maintenance and upkeep of service lines, including curb boxes, from the main to the property line; on April 1, 1932, by order of the Public Service Commission of Indiana, this agreement was made permanent, thus making the company responsible even though it does not own the curb box.

Claims due to accidents involving valve boxes in the street and fire hydrants totaled only nine during this eighteen-year period. The number of claims is comparatively insignificant, but as both of these items are the property of the company, it can be held liable.

All together, 107 "nuisance" claims were filed during the eighteen-year period, 1931-48.

Trend of Claims

The last depression started in 1930 and ran through 1940, with the exception of a slight upturn in 1937 and in the latter part of 1939 and the early part of 1940, and the present boom began early in 1941. With these facts in mind, the author has divided the eighteen-year period into six-year intervals. It was found that 11 claims involving curb boxes were filed in the first six-year period, 1931-36; 37 claims, between 1937 and 1942; and 9 claims, between 1943 and 1948.

During the first six-year period, 5 claims regarding meter pits were received; during the next period, 14 claims; and during the last, 22 claims. Meter pit installations have increased over the past several years, which accounts for the increase in claims in the most recent period.

There were 5 claims involving valve boxes and fire hydrants in the first period, 2 in the second and 2 in the third.

Whether or not the depression had anything to do with the number of claims the author is unable to say, but it does seem odd that most of them were filed in the years toward the end of the depression, and they have since dropped off to a considerable extent, with the exception of meter pit claims.

In 1941 Indianapolis began a program of adjusting curb boxes to grade and by the end of 1942 had covered the entire area served. Since then meter readers have submitted reports on curb boxes in bad condition, which are turned over to the distribution department for adjustment. In this way, the utility keeps up fairly well with curb box maintenance. This program may have had some effect on the reduction of claims after 1941. At the same time meter readers report pits that are in dangerous condition. A letter is written to the property owner advising him that the meter pit belongs to him and that steps should be taken immediately to repair it and avoid the possibility of someone's being injured.

Need for Insurance

The majority of these claims cases are not of a serious nature. Some have been settled for as little as $15.00, while a few others have developed into litigation proceedings and the claimants have been awarded several thousand dollars. Although the amount of money involved is usually not large, every accident must be investigated and a report made to the insurance company, and practically the same preparation is required as if the accident were a serious one. This procedure can become expensive.

In the Indianapolis system, there are approximately 114,500 curb boxes, 17,000 meter pits, 7,847 fire hydrants and 8,500 valve boxes located over the area served. A total of 107 accidents over an eighteen-year period does not seem large, compared to the total number of curb boxes, meter pits, hydrants and valve boxes, but one must not overlook the fact that each of these items is a potential hazard. Moreover, when a claim is filed, it is never known in advance whether it will be settled for $15.00 or for several thousand dollars. Some apparently insignificant claims have later developed into rather expensive cases.

For these reasons, the author does not believe that the Indianapolis Water Co. can afford to be without adequate insurance protection, particularly considering the many possibilities which the large service area provides for the general public to sustain injuries. The utility carries public liability insurance with limits of $100,000 to $1,000,000. The insurance companies have been very cooperative in discussing each claim before settlement is made, an important point since the amount paid out in claims affects the experience rating on which the premium is based.

Causes of Accidents

A summary of accidents over the past eighteen years (1931-48, inclusive) indicates that curb boxes were involved in 57 claims filed. From these claims, it appears that it is not always necessary for a curb box to extend several inches above the ground level for someone to trip over it, although it has often been hard to imagine how anyone could have fallen over the box designated as the culprit. Nor is it necessary for these boxes to be located in sidewalks ordinarily used by the public. Sometimes it would seem that persons have gone completely out of their way to trip over boxes that were nowhere near the sidewalk—in fact, several feet away. On numerous occasions the accident occurred in the early evening, and quite frequently there were no witnesses.

Meter Pit Accidents

The next item on the list is meter pits, concerning which 41 claims were filed during the eighteen-year period mentioned. Meter pits are located on private property and are not owned by the company. However, if someone—even the property owner himself—trips over a meter pit and is injured, a claim is filed with the company. Since these pits are not the property of the company, and since it is not held responsible for their maintenance and upkeep, it is not required to pay damages on very many of these claims. The only time the company becomes seriously involved in a meter pit claim is when a meter reader has visited the premises either on the day of the accident or a few days prior to it; on such occasions the question arises whether or not he fastened the lid securely after reading the meter.

Reference

1. Bourdin, Charles G. Liability for Damage Due to Breaks or Leaks—Undermining Due to Leaks. Jour. A.W.W.A., 40:579 (June 1948).

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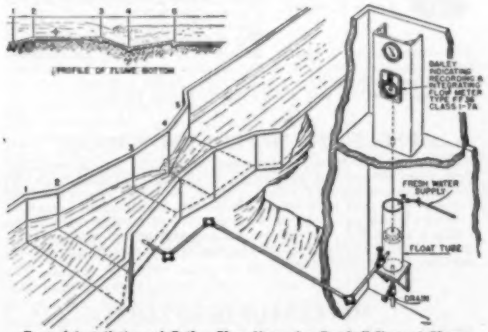
Bailey Flume Meter—Simplicity of installation, low head losses and self-cleaning features of the Parshall Flume have resulted in a greatly increased use of this device for a measurement of Sewage Flow in open channels.

The Bailey Flume Meter is simple and accurate. As shown in the illustration, it consists of a single float which is connected by a flexible cable to the sturdy recording, integrating and indicating mechanism on the panel board. The panel board may be omitted if desired and the recording mechanism mounted on a wall or column. This device may be adapted to any type of open channel metering over any operating range required. Its capacity can be altered in the field by installing new gears and/or cam without disturbing any other parts of the installation.

Standard Bailey Indicating, Recording and Integrating Instruments are used, charts are 12 inches in diameter and uniformly graduated. Instruments may be placed in remote locations by the addition of Bailey Telemetering Systems. Ask for Bulletin No. 62.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Typical installation of Bailey Flow Meter for Parshall Venturi Flume.

Bailey Weir Meter—For measuring flow using any type of Weir notch, highly accurate results can be obtained with a Bailey Weir Meter. This meter is similar to the Bailey Flume Meter and possesses the same features of sturdiness, flexibility and accuracy. Remote transmission can be provided when desired.

Open Float Type Meter—The Bailey Float Type Meter is especially adapted to measure the flow of sewage, sludge, dirty water or other liquids in pipe lines using a Venturi Tube, flow nozzle or eccentric orifice.

This meter is operated through a differential gearing and cam mechanism from floats which rest on the liquid surfaces in float tubes. It is similar in external appearance to the Bailey Flume Meter.

Bailey Registers measuring sewage, sludge and air in an operating gallery at Easterly Sewage Treatment Works, Cleveland, Ohio.

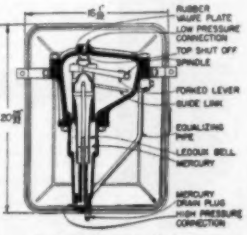
Bailey Fluid Meter—The flow of steam, liquids and gases in pipe lines at high or low pressures can be accurately measured by the Bailey Fluid Meter. A Venturi Tube, flow nozzle, or orifice is used as the differential producing device and the meter indicates, records and integrates on the standard Bailey Register previously described. Remote recorders may be provided by Bailey Telemetering Systems which operate on alternating current.

In addition to the rate of flow, this meter may also record pressure, temperature or liquid level on the same chart.

Ask for Bulletin 301-B.

Air Meters—These meters measure Air Flow in main lines and in individual lines to aeration tanks.

The register is similiar in appearance to the Ledoux bell type, and the flow mechanism is designed to operate on a maximum differential pressure of 88 in. of water. *Described in bulletin No.* 301B.



Section through flow mechanism of Ledoux Bell-type Register.

Controllers—Bailey Controllers utilize standard Bailey Meters and Recorders as the basic measurement source for the automatic control of factors, such as flow, ratio, pressure and liquid level. They are operated by compressed air at approximately 35 lbs. pressure and match perfectly with other Bailey Gages and Registers.

Bailey control is fully automatic, dependable and exceptionally flexible.

Bailey Recorder—Controller.

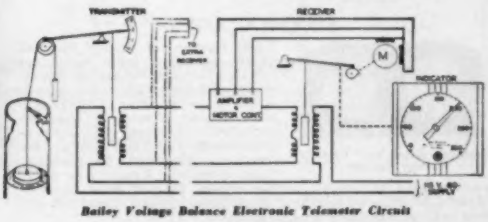
Bailey Telemeters

The Bailey Voltage Balance Electronic Telemeter Circuit is a quick, accurate means of transmitting position over distances. The measure of any factor which can be made to move the core of a small solenoid transformer may be indicated or recorded at a distant receiver. Multiple receivers may be connected to one transmitter; several flow measurements can be totalized.

Large Dial Indicator

Indicators containing the telemeter circuit receiving mechanism may be single or double face, and may have 18, 24, or 30-inch dials. Numerals and indicating pointer are large for easy reading.

Large Dial Indicator



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THE VENTURI METER

The Venturi Meter is recognized as the standard for measuring the flow of water, sewage and air in main pipe lines. It consists of a Venturi Tube installed in the pipe line and a Type M Register-Indicator-Recorder or other instruments connected to the Tube by small pressure pipes. The design of the Herschel Standard Venturi Tube produces a maximum recovery of pressure, which has the economic advantage of lowering pumping costs.

Type M Instruments have unusual sturdiness, and are very popular in the waterworks and sewage fields for their accuracy and reliability. Important features include a 10" indicator at eye level with uniformly spaced scale; improved integrator; 12" uniformly spaced charts; white pyralin dials and interior illumination. The Type M Instrument furnishes continuous indication of flow; a permanent record on 12" chart, and the total quantity on a 3½" counter dial.

Herschel Standard Venturi Tube and Type M Register-Indicator-Recorder.

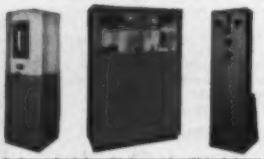
PROPELOFLO METER

Propelofio Meter (large measured, available size in bell and spigot model.

This improved, propeller-type flow meter for main water line metering introduces many new features including streamline Venturi design. A self-contained unit easily installed; registers total flow directly in gallons. Accurate throughout wide range; low loss of head; low first cost and upkeep.

CHLORINIZERS

Builders Chlorinizers accurately meter chlorine gas and produce chlorine water solutions. Special attention has been given to assure completely safe and highly accurate operation. Volumetric Models CVS and DVS have positive chlorine rate indicators with direct reading linear scales. Can be adapted to semi-automatic, program, or automatic proportional operation and conversion from one method of operation to any other may be made in the field. Also available in Gravimetric Model CGS for extreme accuracy over a wide range.



Left and right—Volumetric Chlorinizers Models CVS and DVS. Center—Gravimetric Chlorinizer Model CGS.

FILTER GAUGES

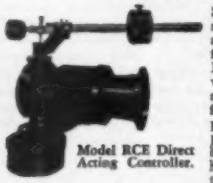
Loss of Head and Rate of Flow Gauge.

Filter Gauges are usually mounted on the operating table convenient to valve controls, but can be mounted on self-supporting floor stands where desirable. The indicator and chart display accurate information gathered by the dependable Builders Diaphragm Pendulum Units. Attractively designed for modern plant interiors. Available in many combinations to indicate and/or record Rate of Flow, Loss of Head, Liquid Level and Sand Expansion. Special types are custom built to engineers' specifications.

FLO-WATCH

A small, medium priced mechanical instrument which measures flow of liquids, steam, air and gas through standard differential producers such as Venturi Tubes, Nozzles and Orifice Plates. This sturdy and accurate instrument is available in a variety of mountings and dial combinations. It is widely used for remote operation of secondary instruments, or the automatic proportional control of dry or liquid chemical feeders. Totalizes by means of fast moving, seven-digit cyclometer-type mechanism, indicates on uniformly spaced 10-inch segmental indicator, and records on uniformly graduated 12-inch chart.

FILTER CONTROLLERS



Model RCE Direct Acting Controller.

Several models are offered, each designed for particular conditions, to automatically maintain constant flow rate through the filter bed. Model RCE features smooth, unwavering control; low loss of head; sturdy, balanced valve; compact flexible design; powerful "floating piston" and exclusive molded tapered piston seal. All rotating bearings anti-friction. Modified for higher pressures and velocities, these controllers serve as Wash Water Controllers or in the effluent lines from pressure filters. Models RCA and RCB are hydraulically operated. Model RCA has a gate type valve with specially shaped seat. Model RCB has a special double butterfly valve of rectangular section and is used for lines over 12" diameter.

PNEUMATIC METERS AND GAUGES

Builders has developed a pneumatic system for use in combination with differential producers, filter plant gauges, chemical feeders, and continuous weighing scales to meter, proportion and control flows and pace secondary feeders. This system permits pneumatic summation of as many as 20 flow meters in one unit. Using a transmitter with a pneumatic unit and a receiver with corresponding calibrated element, the system can be applied advantageously and inexpensively.

METERS FOR OPEN FLOW

Flow through partially filled pipes, sewers and open channels, using a Kennison Nozzle, Parshall Flume, or Weir, where there is a wide range of flow rates, can be accurately measured using standard Builders instruments. The Kennison Nozzle is particularly successful in measurement of raw sewage sludge and trade waste. It is available in sizes from 6" to 36".

CHRONOFLO TELEMETERS

Chronoflo Receiver.

Chronoflo Telemeters bring to a central operating point, from widely scattered locations, accurate records of flow, level, pressure, temperature, gate position and weight. Chronoflo Transmitters are electrically connected by a simple two-wire circuit to Chronoflo Receiving Instruments. Automatic proportional control of Chemical Feeders in step with rate of flow is accomplished by a simple attachment to a standard Chronoflo Transmitter.

WRITE FOR RECOMMENDATIONS, ENGINEERING DATA AND BULLETINS

BUILDERS PRODUCTS

The Venturi Meter • Flo-Watch Mechanical Flow Meters • Chronoflo Electric Flow Meters • Venturi Effluent Controllers • Liquid Level Gauges, Recorders and Controllers • Pneumatic Meters and Controllers • Filter Gauges • Sand Expansion Gauges • Filter Operating Tables • Wheeler Filter Bottoms • Kennison Open Flow Nozzles • Chronoflo Telemeters and Controllers • Conveyoflo Continuous Weighing Scales • Propeloflo Main Line Water Meters • Chlorinizer Chlorine Gas Feeders

SELECTION OF MAIN LINE METERS

With a Set of Charts Designed to Simplify the Problem

J. C. THORESEN, *Engineer*
Builders-Providence, Inc., Providence, R. I.

IN the selection of suitable meters for main gravity and pump discharge pipe lines, price is too frequently the sole determining factor, whereas a closer examination of the proposals may demonstrate that such a decision would be definitely improper from an economic standpoint. This does not assert that the lowest priced equipment is never warranted, but simply that experience has repeatedly emphasized the importance of making an evaluation of design and specifications. These include the reputation of the meter; its anticipated life; materials, workmanship and finish; probable cost of maintenance; character of information furnished, such as size of dials and charts, uniformity of graduations, whether direct reading in units of flow or indirect in nominal values or differentials; and, most important, the friction loss induced. It is not the purpose of this paper to comprehend all of these, but to devote the discussion to the last mentioned, the friction loss, resulting in loss of pressure, or power, or both, occasioned by the insertion of the flow measuring element in the pipe line.

For gravity lines under low heads, the friction loss of the proposed meter should be carefully studied to determine whether objectionable in its effect on the hydraulic gradient. In a pump discharge line, friction loss alone may not be of significance, but when considered together with pipe line size and hours of operation, the combination of these three factors may be of great monetary importance in a 12 months' period.

In general, main line meters operate on the inferential principle: that is, the flow rate is "inferred" from the difference in pressure induced by a "restriction" placed in the pipe line and transmitted to the recording instrument, through which no flow occurs. It is readily appreciated by all water works men that elbows, tees, partly closed valves or other fittings add to pipe line friction loss and must be reckoned with in the design of the system. So it is with meters. Whether water is first lifted to a reservoir or pumped directly through the pipe line, the additional load is reflected back upon the pumps, requiring provision for more horsepower than would otherwise be required, and power always costs money.

Forms of Differential Producers

There are only a few forms of "differential producers" for insertion in pipe lines. Of these, the Venturi Tube and Orifice Plate are by far the most widely employed. They are entirely unlike in their construction.

The Orifice (Fig. III) is essentially a flat plate between flanges of the main pipe. As the flowing water approaches the Plate, the stream lines undergo an abrupt (nearly 90 degree) change in direction; then, after passing through the Orifice opening, start to expand again until finally the pipe line is completely filled. As would be expected, there is considerable turbulence in the surrounding annular space on both sides of the Orifice occasioning a relatively high over all pressure head loss.

The Venturi Tube

The Herschel Standard Venturi Tube (Fig. I) is of "streamlined" proportions. It forms a section of the pipe line. As the flow progresses from the inlet section there is a rapid acceleration of velocity with decreasing pressure until the "throat" is reached, where the speed of flow may be ten or more times as great as at the inlet. After passing the throat, the velocity is decelerated through a gently expanding outlet cone, with consequent gradual regain in pressure. The velocity distribution is equal across the throat and the rate of flow is based upon the throat area. Throughout this interchange of velocity and pressure, there is wall guidance of the flowing stream and turbulence is avoided. For this reason the standard Venturi Tube has definite advantage over the Orifice in the important matter of pressure loss.

Orifice Plates and Nozzles

Fig. II illustrates one form of the "Nozzle", of which there are various designs. The type shown is slightly better than the Orifice in pressure loss characteristics, but not enough to warrant separate consideration. The graph (Fig. IV) shows the comparison of friction loss for the three differential producers mentioned. The steep slope of the two upper curves for the Orifice and Nozzle are in sharp contrast to the Venturi curve: in the Venturi the friction loss changes but a few per cent for a wide range of the throat diameter to inlet diameter ratio (d_t/d_1) in contrast with the other two devices. It will be observed that

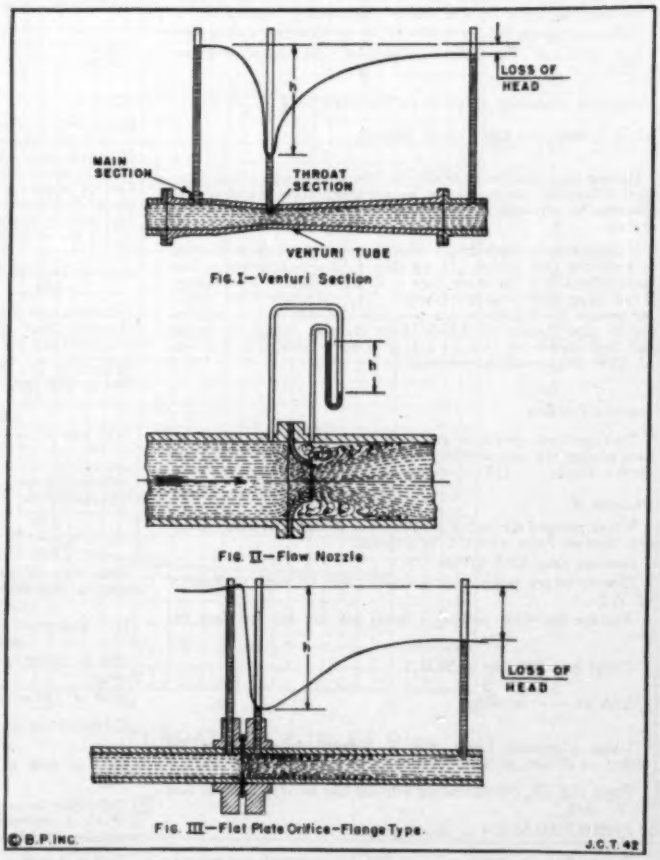


FIG. I—Venturi Section

FIG. II—Flow Nozzle

FIG. III—Flat Plate Orifice—Flange Type.

Figs. I, II and III—Three Forms of Differential Producers for Main Line Metering.

the friction loss is in per cent of the Orifice or Venturi differential head (i.e.—head at inlet minus head at throat) which may reach a maximum of 10 to 20 feet of water, if not more, for accurate metering.

A reduction in the unrecoverable loss of head through an Orifice or Nozzle to a value comparable to the Venturi Tube, by increasing the size of the orifice or nozzle opening, also reduces the differential pressure at any given rate of flow and results in a decreased measuring range.

Example: 10-in. Herschel Standard Venturi Tube with 4-in. throat. Rate of flow 1,400 gallons per minute. $d_2/d_1 = 0.4$.

By following directions for Example 3 given on the Rate of Flow Alignment Diagram, Fig. V, we find differential head = 240 inches of water.

Loss of Head, Fig. IV, 11½% of 240 inches = 27.6 inches of water.

Assume that the average meter recording instrument will not respond accurately to changes in differential of less than .010 inches of water.

Minimum differential equals 1.00 inches for performance accuracy of 1% of differential.

Rate of flow varies as square root of differential.

$\therefore$ accurate measuring range of Venturi $= \sqrt{\frac{240}{1}} =$

15.5 to 1 or 1,400 to 90 G.P.M.

For same unrecoverable loss of head of 27.6 inches Orifice Plate opening would be 7.06 inches (approx.) or $d_2/d_1 = .7$.

Differential pressure for 1,400 G.P.M. = 53.4 inches of water.

Loss of Head (Fig. IV) = 51½% of 53.4 inches of water = 27.6.

Accurate measuring range of Orifice Plate $= \sqrt{\frac{53.4}{1}} =$

7.3 to 1, about one-half that of Venturi.

Having now established briefly the characteristics of two principal differential producers, let us determine their practical significance by recourse to common problems met in water works practice.

Horsepower is measured in foot-pounds of work performed in a definite time period. If we raise a 50 pound weight a distance of one foot, the work done is 50 foot-pounds. By analogy, if we have 8.340 pounds of water (approximately 1,000 gals.) per minute flowing through a pipe line and one foot of head is lost by pipe friction, the result is the same as though the water had been raised one foot, or energy is being expended at a rate of 8,340 foot-pounds per minute.

Practical Problems

Two practical problems are cited to illustrate the method of determining the comparative cost of using Venturi Tubes and Orifice Plates.

Problem A

Water pumped through line containing 16 inch Herschel Standard Venturi Tube with 6½ inch throat.

Average rate, 3,700 G.P.M.

Electric-driven pump with over-all (wire to water) efficiency of 70%.

Average operating period 15 hours per day for 360 days per year.

Power cost 1½c per K.W.H.

$d_2/d_1 = \frac{6.5}{16.0} = .405$

Using Alignment Chart, Fig. V, Venturi differential = 240 inches = 20 feet of water.

From Fig. IV, corresponding friction loss = 11½% of 20 feet = 2.3 feet.

3,700 G.P.M. × 8.34 = 30,858 pounds.

Energy Loss = 30,858 × 2.3 = 70,973 foot-pounds per minute; and $\frac{70,973}{33,000} = 2.15$ horsepower.

Equivalent electrical loss = 2.15 × .746 = 1.605 kilowatts.

Corrected for motor and pump efficiency $\frac{1.605}{.70} = 2.29$ KW.

Cost of power per year

= Hours × KW. Loss × Cost per K.W.H. = $185.00
(360 × 15) × (2.29) × (.015) = 1

From Fig. V, an Orifice Plate for same maximum flow would have an opening 8.25 inches diameter.

$d_2/d_1 = \frac{8.25}{16} = .515.$

Loss through Orifice = 71% of differential = .71 × 20 = 14.20 feet.

HP. Loss $= \frac{14.20}{2.3} \times 2.15 = 13.3.$

Cost of Power per year $= \frac{13.3}{2.15} \times \$185.00 = \$1,145.00.$

Cost of 16 inch Venturi Tube	$640.00
Cost of 16 inch Orifice Plate and Flanges	65.00
Difference	$575.00

Saving in power consumption by using the Venturi Tube, $1,145.00 — $185.00 = $96.00 per year.

Omitting depreciation, $\frac{960}{575} = 167\%$ return on investment.

Conclusion: In comparison with the Orifice, the Venturi Tube would pay for itself in about six months and should be selected.

Problem B

Motor-driven pump operating 15 hours per day, 350 days per year = 5,250 hours per year.

Discharge line, 4.00 inches.

Wire to water efficiency, 60%.

Cost of power, 2c per K.W.H.

Pump discharge average rate, 100 G.P.M.

4.00 inch Venturi Meter designed for a maximum of 350 G.P.M.; throat diameter, 2.00 inch.

$d_2/d_1 = \frac{2.00}{4.00} = .50.$

Following the procedure outlined in "Problem A" and using Alignment Chart, Fig. V, differential pressure across the Venturi connections for 100 G.P.M. is 18¾ inches water.

From Fig. IV, friction loss = 10½% of 18¾ inches = 1.97 inches or .164 feet.

$$\text{H.P. loss} = \frac{100 \times 8.34 \times .164}{33,000} = .00415.$$

Substituting an Orifice Plate for the Venturi Tube the 18¾ inches differential (Fig. V) gives Orifice opening of 2.49 inches

or $d_2/d_1 = \frac{2.49}{4.00} = .622.$

From Fig. IV, friction loss = 65.0% of 18¾ inches = 11.32 inches or .945 feet.

H.P. loss $= \frac{.945}{.164} \times .00415 = .024.$

.024 — .00415 = .0199 excess of H.P. loss of Orifice over Venturi.

.0199 × .746 = .0148 K.W.

Corrected for pump efficiency.

$\frac{.0148}{60} = .0247$ K.W.

Difference in cost of power per year of operation = cost per K.W.H. × electrical loss × hours of operation = .0199 × .0247 × 5,250 = $2.58.

Cost of 4 inch × 2 inch Venturi Tube	$125.00
Cost of Orifice Plate and Flanges	30.00
Difference	$ 95.00

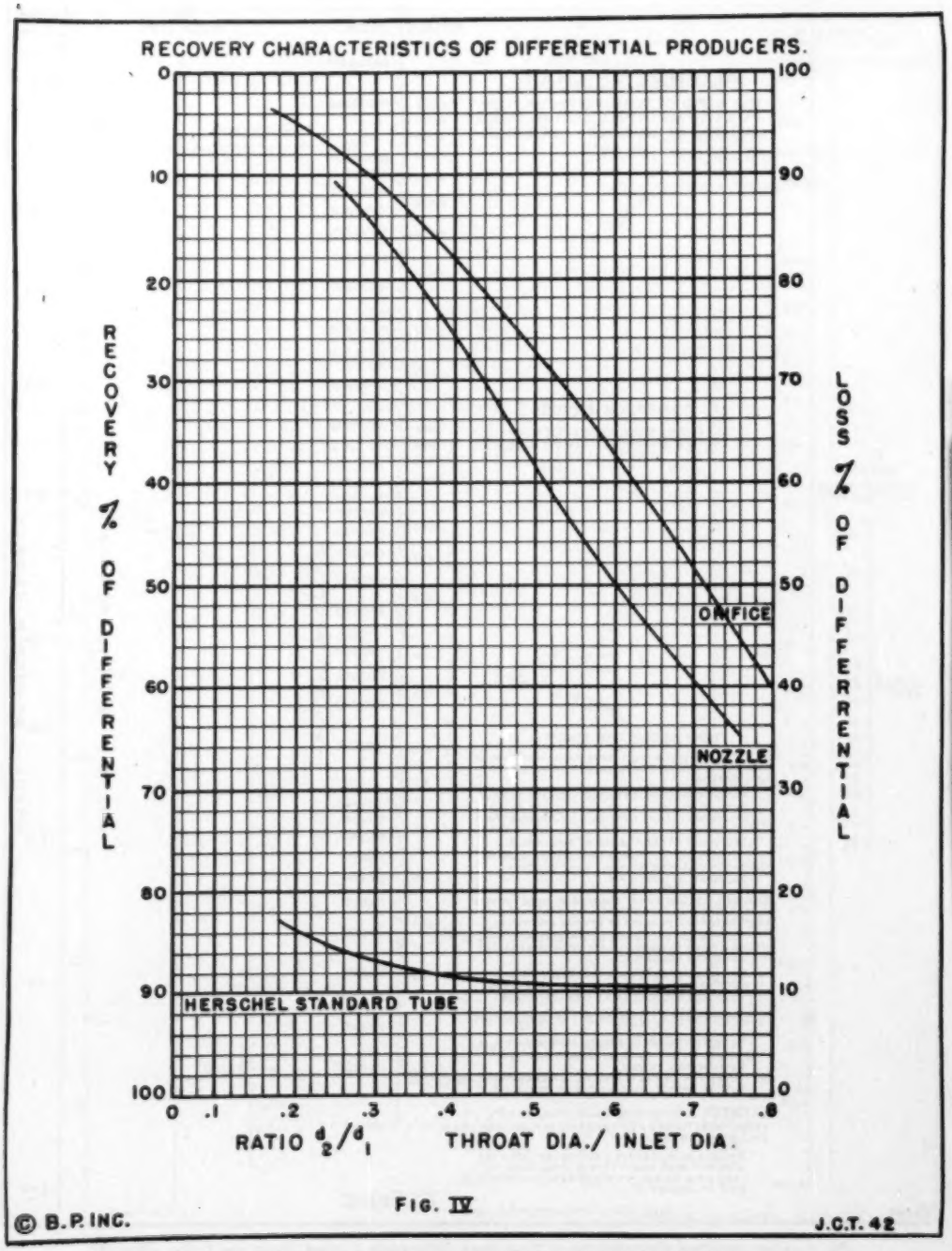
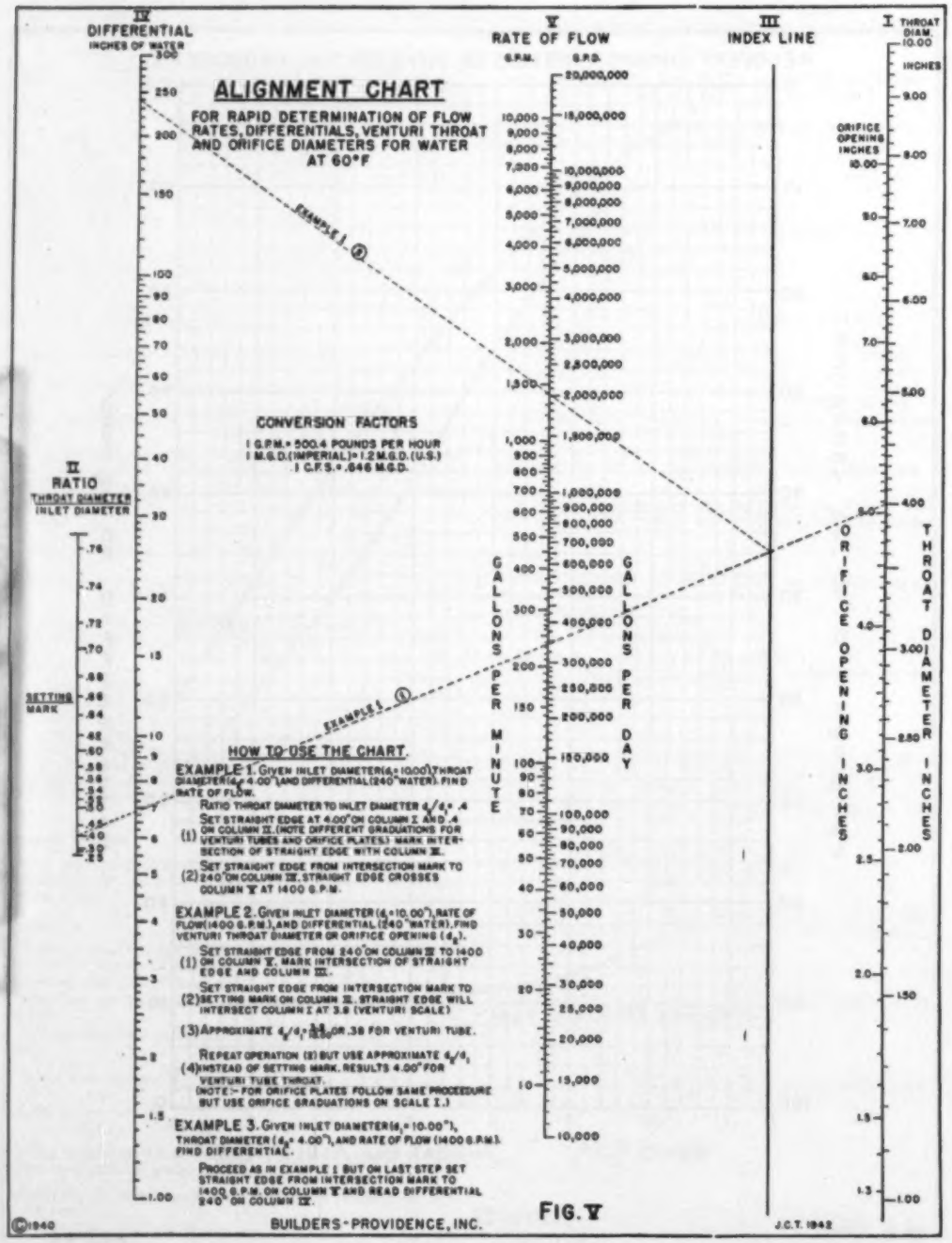


Fig. IV—Recovery Characteristics of the Venturi Tube, Nozzle and Orifice.


ALIGNMENT CHART
FOR RAPID DETERMINATION OF FLOW RATES, DIFFERENTIALS, VENTURI THROAT AND ORIFICE DIAMETERS FOR WATER AT 60°F
IV DIFFERENTIAL INCHES OF WATER
V RATE OF FLOW G.P.M. G.P.D.
III INDEX LINE
I THROAT DIAM. INCHES
ORIFICE OPENING INCHES
II RATIO THROAT DIAMETER / INLET DIAMETER
SETTING MARK
GALLONS PER MINUTE
GALLONS PER DAY
THROAT DIAMETER INCHES
CONVERSION FACTORS
1 G.P.M. = 500.4 POUNDS PER HOUR
1 M.G.D. (IMPERIAL) = 1.2 M.G.D. (U.S.)
1 C.F.S. = .646 M.G.D.
EXAMPLE 1
EXAMPLE 2
HOW TO USE THE CHART.
EXAMPLE 1. Given inlet diameter (d_1 = 10.00") throat diameter (d_2 = 4.00") and differential (240" water). Find rate of flow.
Ratio throat diameter to inlet diameter d_2/d_1 = .4
(1) Set straight edge at 4.00" on column I and .4 on column II. (Note different graduations for venturi tubes and orifice plates.) Mark intersection of straight edge with column III.
(2) Set straight edge from intersection mark to 240" on column IV. Straight edge crosses column V at 1400 G.P.M.
EXAMPLE 2. Given inlet diameter (d_1 = 10.00"), rate of flow (1400 G.P.M.), and differential (240" water). Find venturi throat diameter or orifice opening (d_2).
(1) Set straight edge from 240" on column IV to 1400 on column V. Mark intersection of straight edge and column III.
(2) Set straight edge from intersection mark to setting mark on column II. Straight edge will intersect column I at 3.9 (venturi scale)
(3) Approximate d_2/d_1 = 3.9/10.00 or .38 for venturi tube.
(4) Repeat operation (2) but use approximate d_2/d_1 instead of setting mark. Results 4.00" for venturi tube throat.
(Note :- For orifice plates follow same proceedure but use orifice graduations on scale I.)
EXAMPLE 3. Given inlet diameter (d_1 = 10.00"), throat diameter (d_2 = 4.00"), and rate of flow (1400 G.P.M.). Find differential.
Proceed as in example 1 but on last step set straight edge from intersection mark to 1400 G.P.M. on column V and read differential 240" on column IV.
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BUILDERS-PROVIDENCE, INC.
FIG. V
J.C.T. 1942

Fig. V—Chart for Rapid Determination of Flow Rates, Differentials, Venturi Throat and Orifice Diameters.

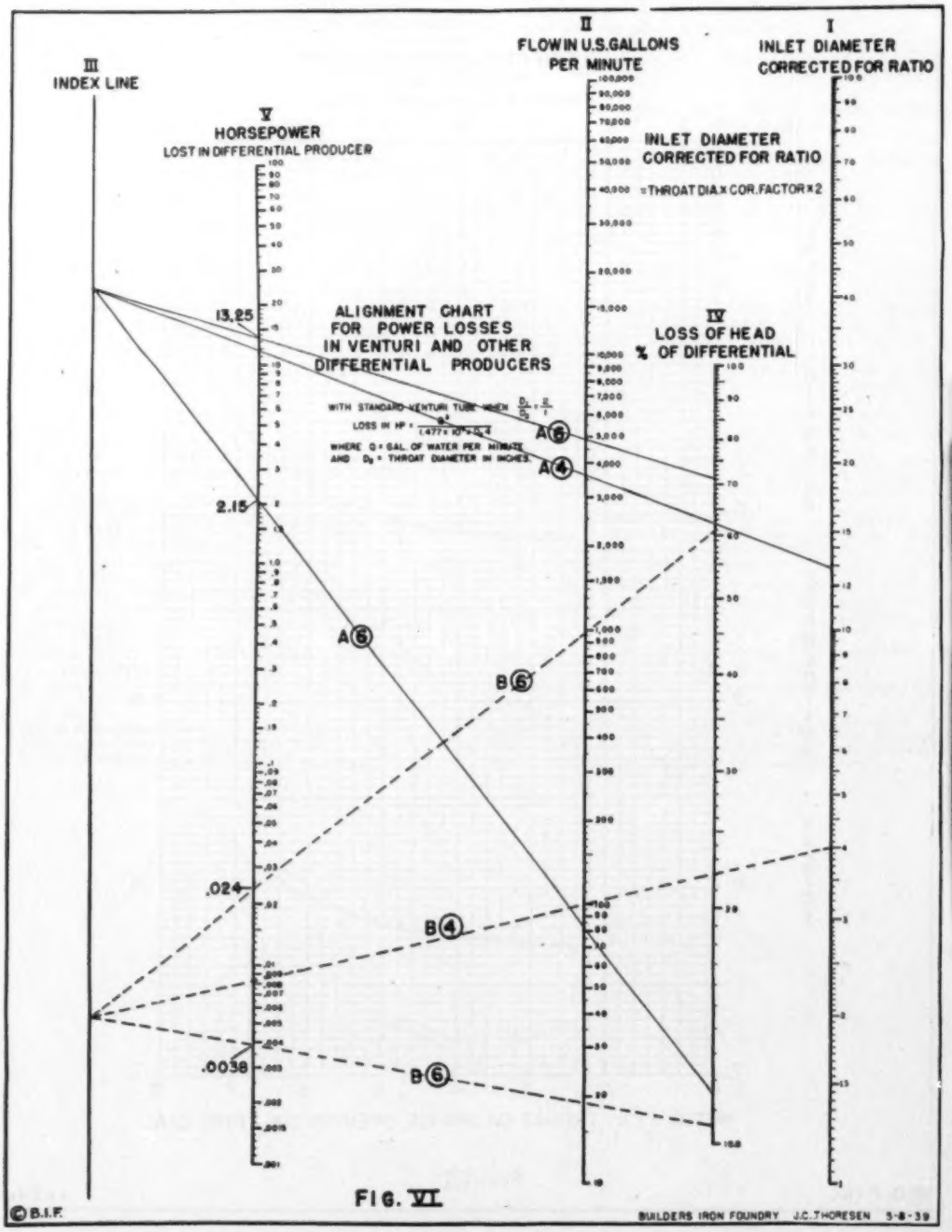

Fig. VI—Chart for Power Losses Through Venturi Tubes and Other Differential Producers.

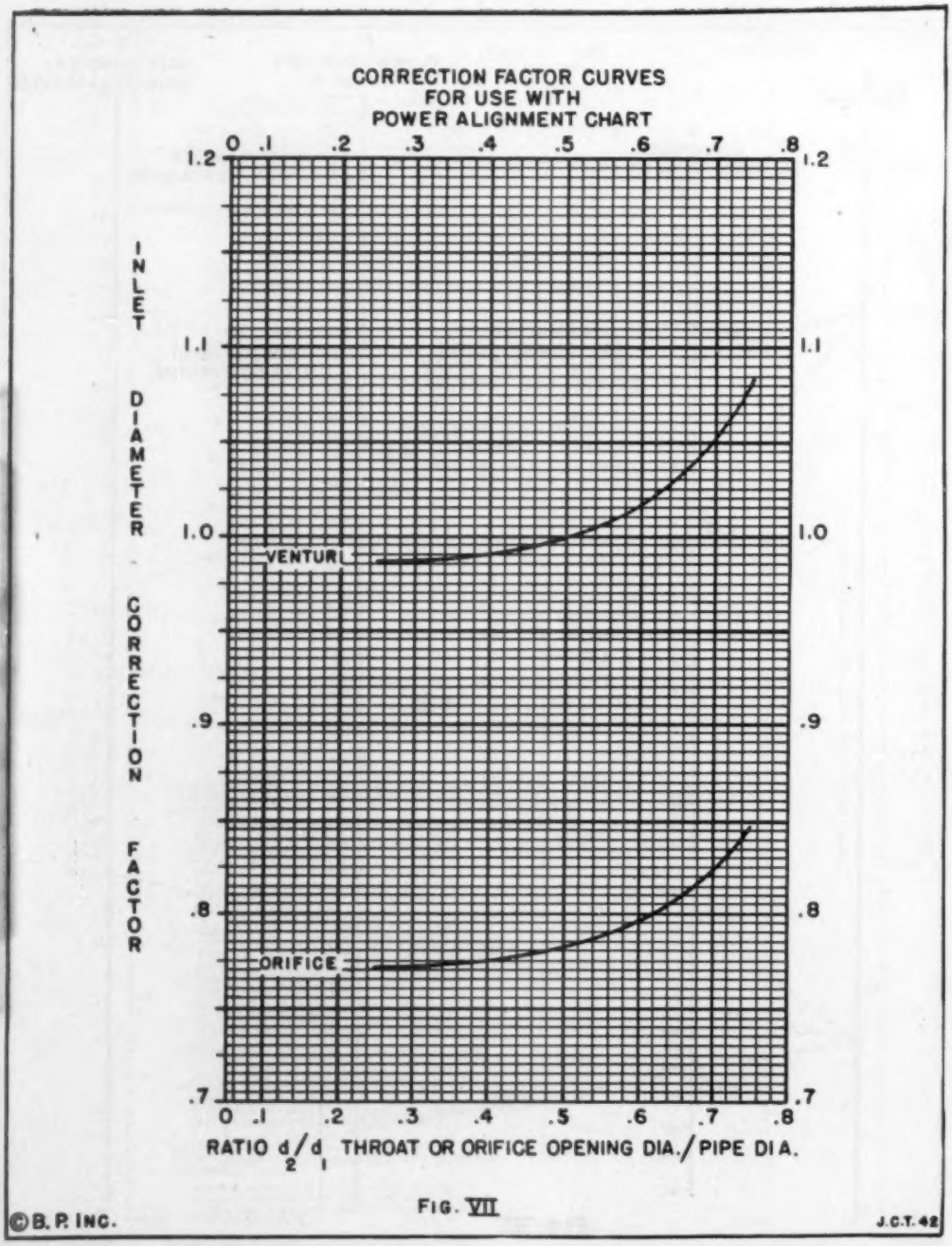

Fig. VII—Correction Factor Curves. (For use with Alignment Chart for Power Losses—Fig. VI.)

Conclusion: On the basis of a saving of power of only $2.58 per year, it is readily apparent that it will take 36 years to pay the increased cost of the Venturi Tube, and therefore, from a monetary viewpoint, the Orifice Plate should be selected.

To simplify the calculations needed for any meter installation a Horsepower Alignment Chart (Fig. VI) has been prepared. It is easily used and the results are accurate to within a few per cent. Its application to the two problems calculated in the preceding paragraphs is illustrated:

Problem A

16 inch × 6½ inch Venturi Tube compared with 16 inch Orifice Plate having 8.25 inch opening.

Flow Rate, 3,700 G.P.M.

(1) For the Venturi Tube $d_a/d_1 = \frac{6.5}{16.0} = .406$

For the Orifice Plate $d_a/d_1 = \frac{8.25}{16.0} = .515$

(2) From Fig. VII, "Correction Factor" for the Venturi Tube is .992; for the Orifice Plate .783.

(3) To obtain the "Inlet Diameter Corrected for Ratio" for the Venturi Tube or Orifice, multiply the throat diameter or Orifice opening by correction factor × 2. For the Venturi Tube, 6.2 × .992 × 2 = 12.89. For the Orifice Plate 8.23 × .78 × 2 = 12.88. Theoretically, these two products should be exactly the same; their close agreement checks the accuracy of the work.

(4) From the point 12.89 on the Corrected Inlet Diameter Scale (I) draw a straight line through 3,700 G.P.M. on Rate of Flow Scale II. Extend this line until it intersects the Index Line.

(5) From the "Recovery Characteristics" Chart, Fig. IV, the friction loss of a Venturi Tube with d_a/d_1 ratio of .406 is 11.5% of differential; for the Orifice Plate with d_a/d_1 ratio of .515 it is 71%.

(6) From the point previously located on Index Line III of Alignment Chart, draw two lines, one to the 11.5% point on the Loss of Head Per Cent of Differential Scale IV; the other to the 71% point on the same scale.

(7) These two lines cross the Horsepower Scale V and the points of intersection represent the horsepower loss for the Venturi Tube and Orifice, respectively 2.15 and 13.25.

(8) The difference in cost of operation of the two differential producers can be quickly determined by using the following simplified formula:

Excess cost of using Orifice Plate over Venturi Tube

$$= \frac{(HP_o - HP_v) \times K \times T \times C}{E}$$

In which:

HP_o = Horsepower Loss for Orifice Plate

HP_v = Horsepower Loss for Venturi Tube

K = Conversion Factor, HP to KW = .746

T = Total hours of operation

C = Cost of Power per KWH

E = Wire to water efficiency of pumping unit (motor and pump) usually 50% to 80%.

Substituting the values in Problem A

Excess cost of Orifice

$$= \frac{(13.25 - 2.15) \times .746 \times (3600 \times 15) \times .015}{.70} = \$962.00$$

This corresponds almost exactly with the previously calculated difference in cost of $1,145 — $185 = $960.00.

Problem B

4.0 inch × 2.0 inch Venturi Tube compared with Orifice having 2.49 inch opening. Flow rate 100 G.P.M.

(1) For the Venturi Tube $d_a/d_1 = \frac{2.0}{4.0} = 0.5$.

For the Orifice

$$d_a/d_1 = \frac{2.49}{4.00} = .622$$

(2) From Correction Factor Chart (Fig. VII) correction factor for Venturi Tube is 1.00 and for Orifice Plate .80.

(3) Inlet diameter corrected for ratio: Venturi Tube 2.0 × 1.00 × 2 = 4; Orifice Plate 2.49 × .80 × 2 = 4.

(4) From point 4 on Corrected Inlet Diameter Scale I, draw a line through the 100 mark on the Rate of Flow Scale II. Extend this to the Index Line III.

(5) From Chart, Fig. IV, friction loss of a Venturi Tube with d_a/d_1 ratio of .50 is 10½% of the differential; for an Orifice Plate with a d_a/d_1 ratio of .622 it is 60.5%.

(6) From the point previously located on Index Line III, of Alignment Chart, draw two lines, one to the 10.5% point on the loss of Head Per Cent of Differential Scale IV and the other to the 60.5% point.

(7) The points of intersection of these two lines with the Horsepower Scale represent the horsepower loss for the Venturi Tube and Orifice, respectively, .0038 and .024.

(8) Difference in cost of operation

$$= \frac{(HP_o - HP_v) \times K \times T \times C}{E}$$

$$= \frac{(.024 - .0039) \times .746 \times 5250 \times .02}{.60} = \$2.63$$

This solution by use of the diagrams agrees very closely with the calculated figure of $2.60.

Following the procedure as outlined and with the aid of the several diagrams presented anyone, after a little preliminary practice, can by their use quickly determine the most economical type of meter for any installation under consideration.

R. W. SPARLING

MANUFACTURER OF

MAIN-LINE WATER MEASURING EQUIPMENT

Box 3277, LOS ANGELES 54 — 1500 South Western Avenue, CHICAGO 8
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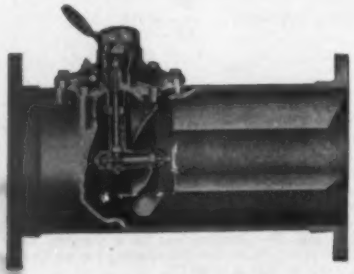


INDICATORS • RECORDERS
TOTALIZERS • CONTROLS

TOTALIZATION is the primary step in all Sparling Main Line Meters. Accuracy at rated ranges is guaranteed within 2 per cent, and loss of head is negligible!

SPARLING Meters are *complete* Totalizing units, installed as easily as a length of the pipe itself. They can be mounted on the suction or the discharge side of pump.

The Compound meters are installed horizontally, but the tube and saddle type Sparling Meters may be installed horizontally, vertically, or on an angle.

Registration is in any quantity unit desired.

Flow-rate indicators and recorders are available for use with Sparling Meters if, as and when required. The mercury-governor type, with circular charts for 24-hour or 7-day records, are mechanically controlled within 15 feet of the meter, or electrically controlled at any distance. They may be Pedestal, Wall or Panel mounted.

The differential type, shown above, has a straight-reading 60-day strip roll chart. Indicator scale is calibrated in two flow equivalents. Operated by electric remote control.

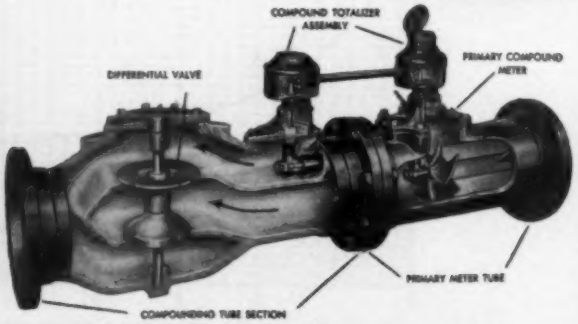
Mechanical or electric controls for auto-metered chemical feed are available.

FLANGED TUBES—2-inch to 36-inch
SCREW TUBES—2-inch to 6-inch
BELL & SPIGOT—4-inch to 36-inch
SADDLE-MOUNTED—6-inch to 72-inch

●

Fire Hydrant Meter

Easily attached to the hydrant and connected to fire hose for accurate measurement of flows from 30 gpm up, with only 1 pound per square inch pressure loss at 200 gpm. Weight, 20 pounds. With Standard Hose Coupling (2½"), $200.



COMPOUND Meters for Mains 6-inch to 36-inch
Consistent accuracy over flow-range as wide as 1-to-125

Differential valve cracks at about one pound per square inch back pressure from the smaller meter. The smaller meter measures all flows below the minimum accurate range of the larger meter. Both meters drive through ratchet clutches to a common totalizer, which thus operates with the faster turning meter.

Bulletin 310 comes upon request

PROPELLER-TYPE METERS

For Main-Line Metering

JAMES M. MONTGOMERY*
Consulting Engineer, Los Angeles, Calif.

THE principle of the current meter has been used as a primary metering element for the measurement of stream flows for over thirty years. During the past fifteen years this same current meter principle has been applied as a primary element for the measurement of main-line flows by R. W. Sparling, of Los Angeles, and has proven itself well suited for this purpose.

The Propeller-Meter

The propeller-type meter, as illustrated in Figure I, is made up of a six-bladed propeller approximately eight-tenths of the pipe diameter mounted transversely in the center of the pipe. The propeller is made of a plastic material, having a specific gravity of approximately one, and is suitable for use in either cold water or hot water up to 300° F. The propeller practically displaces its own weight in water and is mounted on ball bearings which allow it to rotate freely in the stream of water.

Calibration

Experiments and experience have shown that a propeller will rotate in direct proportion to the velocity of water in a pipe at all flows above an approximate pipe velocity of one-half linear foot per second. The index, or the number of cubic feet passing through the pipe for each turn of the meter shaft, is determined from volumetric tests. From this index proper gears are furnished for direct totalization of the flow.

Characteristics

The current metering principle has certain characteristics that make it particularly well adapted for main-line measurement, as the action of the propeller is solely dependent upon the velocity of flow in the line. The pressure requirement is only such as to always maintain a full pipe of water. The loss of pressure caused by the metering element in sizes 6" and larger does not exceed six (6) inches of water at normal maximum pipe velocity.

Continued accuracy of the current type meter is dependent chiefly upon maintaining a clean metering section and a propeller free from incrustation. The plastic propeller has proven itself well suited for this purpose as it is practically inert and will resist both corrosion and electrolytic action. In order to maintain a uniform meter section the propeller assembly may be mounted in either a cast-iron or steel tube having a bronze liner.

Installation

The metering element may be installed directly on existing pipe lines by means of a saddle either bolted or welded directly on the main. In such installations it is important that the inside diameter of the pipe be accurately determined. In all installations the meterhead may be removed from the pipe line very quickly and easily and it is normally good practice in sizes 12" and smaller to make a yearly inspection and sizes 16" and larger, every five years.

In selecting the proper location for the metering element it should be kept in mind that a normal flow of water, free from either spiralling or jet action, is required for accurate results. The spiralling effect that may be caused in a flow of water passing through a series of elbows, can be largely corrected by installing straightening vanes in the line preceding the meter.

Various forms of such vanes are in use but a very simple and effective correction may be made by the installation of three vanes — each approximately one-third the pipe diameter and two and one-half pipe diameters long, set at 120 degrees to each other in the pipe. These vanes will not eliminate a disturbance caused by a partially open gate-valve, but are effective for double elbows or other standard fittings and with such vanes the meter element may be installed with but two pipe diameters of straight approach.

One pipe diameter downstream is normally sufficient for all installations. Unless approximately ten pipe diameters are available ahead of the meter, it is always good practice to use the straightening vanes. When the metering element is installed complete, with either a flange or bell and spigot tube, the three vanes mounted directly inside this metering section constitutes a complete unit ready for installation.

The metering element can be installed in either a vertical or horizontal pipe line and is suitable for mounting on either the suction or discharge side of a centrifugal pump.

Compound Design

Figure II is a sectional illustration of a compound meter suitable for use where an extremely wide range of flow measurement is required. A range of 150 to 1 is possible. A compound unit consists chiefly of two propeller-type meters working in series

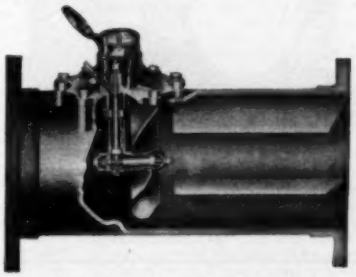


Fig. I—Cutaway View of Propeller Meter Note the flow straightening vanes in the tube, the whole unit ready for insertion as a single piece in the main-line.

through a pair of rachet clutches, allowing the meter revolving at the highest speed to drive the totalizing register. On the very low flows the large meter will under-register and thus allow the small meter to drive the totalizer. As the flows increase a pipe velocity is reached where the large meter has come into step and the small meter is operating at a high capacity. At this point the pressure loss caused by the small meter operating on the differential area of the compounding valve forces the valve to lift itself and allow the higher flow to by-pass the small meter.

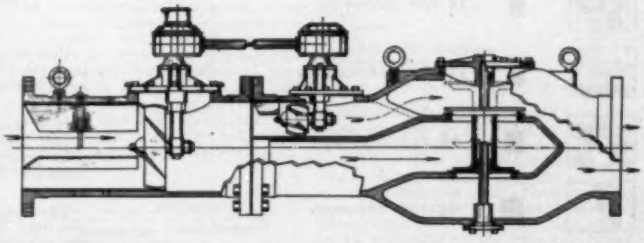


Fig. II—Section Through Propeller-Type Compound Meter Note valve which closes on low flows to cause entire flow to pass through small meter.

Although the minimum flow is considerably above that of the standard domestic compound meter it is well adapted for main-line measurement as the pressure loss caused by the entire unit does not normally exceed two pounds at maximum flow.

*President, J. M. Montgomery & Co., Engineer.

Indicating and Recording Elements

A rate-of-flow indicating and recording instrument may be used in conjunction with the straight totalizing primary element. The primary step of a current type meter is direct totalization. If the rate-of-flow indication is desired it must be obtained through a secondary step normally involving either a governor bowl or a friction plate revolving at a constant speed with a follower locating itself on the plate by impulses from the primary element.

Fig. III—Typical Sparling Indicator-Recorder of the Mercury Governor Type.

Figure III illustrates the recording instrument involving a governor bowl which is driven either mechanically up to 15 feet from the metering element, or electrically to any distance required. The governor bowl consists chiefly of a float riding in the center of a mercury well. As the governor revolves, the mercury, through centrifugal force, finds its way through a small needle-valve to the outer chamber of the bowl, allowing the float in the center to have a rising and falling action in proportion to the revolving speed of the bowl. This type of governor is effective over approximately a 6-to-1 range and is extremely simple and well suited for normal pump measurement.

A recording instrument utilizing the revolving friction plate, with a follower locating itself by impulses from the metering element, as mentioned above, produces a straight line of rate indication over approximately 25-to-1 range and is well suited for recording flows of main distribution or consumption lines.

Recorders can be adapted to show the combined flows of two or more pipe lines and combinations may be furnished showing the net total of several lines where the flow of any one pipe may be in either forward or reverse direction.

Application in Chemical Feed Control

Automatic control of chemical feeders by either mechanical or electrical means is readily obtainable from a current meter element as the shaft of the meter is revolving in direct proportion to the flow and considerable load may be applied without affecting the rotating speed of the propeller.

If given the period inspection required by any primary metering element, the characteristic of low pressure loss and accuracy over a wide range of flow allows the principle of the current meter to fill an important part in the waterworks field.

The propeller-type meter is not suitable for measuring raw sewage and is not generally recommended for measurement of a sewage effluent unless it has passed through a filter bed. Care must also be taken when installing such meters on raw water gravity lines that screens are provided at the inlet structure to prevent excessive algae or weeds from passing down the pipe and stalling the meter propeller.

WHERE THE WATER DOLLAR GOES

Here is an interesting and enlightening chart taken from the 22nd Annual Report of the Water Department, Springfield, Ill.

It is based on a survey made by H. V. Pedersen, Water Supt., at Marshalltown, Iowa, to determine what percentage of water in the average consumer's home goes for various uses.

The Springfield folks have taken these percentages and made them more real to the customer, by showing him that out of every dollar paid for water used it only cost him 1 cent to wash his car, only 4 cents for laundry work at home, 3 cents for sprinkling in summer.

USE OF CONE VALVES IN DISTRIBUTION SYSTEMS*

LAURIE M. LEEDOM
Construction Engineer
Division of Water, Newark N. J.

CONTROL valves represent one of the few improvements made in distribution system equipment during the past 40 or 50 years. Several valves have been devised which operate quite easily even against unbalanced hydraulic pressure. One such device is the plug or cone valve. Basically, this valve is a plug with a transverse hole in it. When the valve is inserted in a pipeline in the open position, water will flow unobstructedly. By turning the plug 90 deg., the flow is stopped. This is the principle of a stopcock. Both are simple and both can be operated against unbalanced head with little effort. This is a decided advantage over a gate valve, which, like a sluice gate, becomes harder to operate as the difference in pressure increases across the valve.

The cone valve would therefore appear to be the ideal valve, and in some respects perhaps it is. But there are other factors to consider beside its mechanical merits. Like so many good things in this world it has the unfortunate disadvantage of being expensive. Size for size, it is many times more costly than a gate valve. Much of this increased cost is due to a clever mechanism which rotates the plug. Unlike the stopcock, which rotates in full contact with the valve body, the plug of the cone valve must be raised slightly to provide clearance before rotating and then lowered to seat, after it has turned 90 deg. To perform this complicated mechanical operation by the continuous rotation of a single operating nut requires a lifting, plug-rotating and seating mechanism, which materially increases the cost of the valve.

The disparity in cost between cone and gate valves can be brought more nearly in line by using a size of cone valve much smaller than would be considered for a gate valve. This is possible because a cone valve, when open, presents a smooth bore to the flow of water, and, when the velocity is increased by the reduction in diameter, there are no cavities or projections inside the valve to retard the water. The hydraulic loss through the cone valve is equivalent to that of a piece of pipe of similar length and diameter. Very little hydraulic loss is caused by the reducer, and if the increaser is long enough the total loss is quite small.

Cone Valve Operation

The cone valve shows up to best advantage in operation. Since unbalanced head has little or no effect, it can usually be operated by one man, and since it has relatively few turns it can be operated in a few minutes. With present-day prices of labor, this is a distrinct advantage.

In the Newark Water System there is a 60-in. pipeline from Cedar Grove Reservoir to a point in the city. The line is 6.8 miles long and has three 48-in. gate valves in it, each of which has about 450 turns and requires six or eight men when operated by hand. Operating one of these valves requires a minimum of six to eight man-hours, because the men must rest periodically or be spelled by others ready to take their place. It is a slow and laborious job.

Five years ago a 24-in. cone valve was installed in this line (see Fig. 1 and 2). This valve can be operated by one man and, since there are only 72 turns, the line can be shut down or opened in a few minutes.

A reduction from 60 to 24 in. may seem at first to be too great. However, as the average flow in this line is 50 mgd., the velocity is 3.94 fps. Reduring the diameter to 24 in. increases the velocity to 24.60 fps. through the cone valve. Computing the loss of head through a Venturi tube of similar dimensions shows a total of about 1.4 ft. For a maximum flow of 80 mgd., the loss of head across the valve and its reducer and increaser is 3.5 ft. These losses are about equal to 1,200 ft. of 60-in. pipe with a Hazen-Williams coefficient of 100. Because the Newark water system operates solely by gravity, this loss is not too serious.

The reducer on this cone valve installation has an included angle of 30 deg., while that of the increaser is 8 deg. Both pieces are made of welded sheet steel, flanged at the small end and bolted to the cone valve. The large ends are welded to the pipeline. A coating, inside and out, of bitumastic enamel gives corrosion protection to the steel. The decreaser and increaser on this initial cone valve installation were made concentric, but all subsequent pieces have been designed as eccentric. They have a double advantage. By placing the straight side on the bottom they produce a uniform grade of invert through the valve installation and, in so doing, lower the cone valve, making it more accessible and reducing the vault ceiling elevation. The latter is sometimes a very important consideration if cone valves are to be installed in mains laid with shallow cover. Eccentric reducers and increasers also facilitate inspection of the valve from inside the pipe and permit draining the line during unwatering operations.

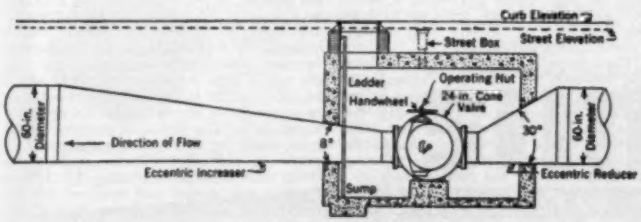


FIG. 1. *Cone Valve Installation*

It has been found that most large disc valves are almost, if not entirely, impossible to close under greatly unbalanced pressure. Disc valves in 24- and 36-in. sizes are extremely hard to close when the difference in pressure across the valve

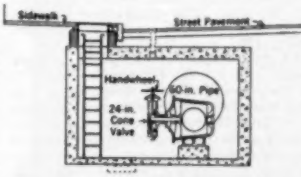


FIG. 2. *Cone Valve Section*

amounts to 100 psi. or more. The seat rings are often badly scored by such an operation and a bent stem also frequently results. It would seem, then, that cone valves are the logical answer to such a problem. If pressure throughout the system is obtained by gravity rather than by pumping, small cone valves with properly designed Venturi reducers and increasers can be installed without adding to the cost of delivering water.

Graphitic Corrosion

Even though cone valves are installed in vaults and do not come in contact with the soil, it is believed advisable to specify corrosion-resistant cast iron for the body of the valve and the plug. An examination of a number of Newark gate valves which had been in service for many years showed that the discs and the inside of the valve bodies had deteriorated from graphitic corrosion. Some seat rings had been sheared off the discs because of the weakened condition of the metal forming the shoulder on the disc. Newark specifications for cone and air valves therefore require the cast-iron composition shown in Table 1. This will produce dense, corrosion-resistant castings with a tensile strength about twice that of ordinary gray iron (1). At present the specification of alloy cast iron increases the time of delivery and adds to the cost per pound, because it constitutes a special order. Valve manufacturers, however, state that, if alloy cast iron were generally specified for valve bodies and parts instead of ordinary cast iron, the water departments could get much better castings and the increased cost would be negligible.

TABLE 1

Composition of Cast Iron in Valves

Element	Quantity per cent
Total carbon	3.00±0.15
Silicon	2.00±0.25
Manganese	0.75±0.15
Nickel	1.05±0.15
Chromium plus molybdenum	0.35±0.05
Phosphorus (max.)	0.30
Sulfur (max.)	0.12

Everdur* bolts and bronze nuts are specified for the assembly of cone valves.

*Reprinted from JAWWA. Vol. 41, p. 84 by permission.

*A product of the American Brass Co., Waterbury, Conn.

Although they cost more than steel bolts, they are not subject to corrosion and, regardless of age, can be readily removed and used again. Steel bolts may rust and may have to be burned off and replaced if their removal becomes necessary.

Newark Installations

The city of Newark is now installing four cone valves to control the flow in large mains. A 16-in. automatic pressure-regulating valve is being placed in a 42-in. main and an 18-in. automatic valve in a 48-in. main. A 24-in. and a 30-in. manual valve are being installed at different points in a 60-in. main. It is intended to place 18- and 20-in. cone valves in the throats of 42- and 48-in. Venturi meters, respectively.

At a main control center in the Newark system, a 60-in. pipe is connected to several intersecting 36- and 48-in. mains. The pipes were laid before the day of cone valves, and the various connections were made by means of manifolds consisting of three 20-in. connections. Each connecting pipe is equipped with a 20-in. gate valve, and some of the manifolds are double-gated. The purpose of the manifold connections was to make operation easier, but, since some of the 20-in. valves have nearly 200 turns, it is still a laborious and time-consuming job to make a shutdown, even when pressures are balanced. When pressures are unbalanced, a shutdown is almost impossible.

A number of years ago a 36-in. main broke and it was several hours before a complete shutdown could be effected. The pressure on the upstream side of the valves was about 100 psi., while downstream it was about zero. The valves were extremely difficult to operate and extensive damage was sustained until the flow of water could be stopped.

The outmoded manifolds can now be replaced with single connections, each equipped with a cone valve. When completed, sixteen cone valves will replace forty-five 20-in. and 36-in. gate valves at the control center and will provide even greater flexibility of operation than is now possible with the old connections. In the new layout, 36-in. pipes will be equipped with 14-in. cone valves, 48-in. pipes with 18-in. valves and the 60-in. pipe with 24-in. valves.

Added Safety Factor

Cone valves have another advantage over gate valves: they can be installed in such a way as to be safer to operate. Since a cone valve may be operated by one man, the vault can usually be so constructed that a portion of it will extend under the sidewalk where a manhole can be placed. Other things being equal, the operation of a cone valve from within a vault is much safer than the operation of a gate valve, which is almost invariably in the street in the midst of traffic.

A cone valve can be operated quickly and with comparatively little effort. The significance of such virtues in a valve can best be appreciated by any water works operator who has seen his men push and tug at a recalcitrant gate valve, expending great energy and consuming precious minutes, after a break has occurred on a large water main.

Reference

1. Leedom, Laurie M. Graphitic Corrosion of Cast Iron. Jour. A.W.W.A., 38:1392 (Dec. 1946).

METHODS OF CLASSIFYING COMMUNITIES FOR FIRE INSURANCE RATINGS*

H. R. BOGARDUS
Engr. & Asst. Supt.,
The Fire Insurance Rating Organization of N.J.

"Municipal classifications are determined by the application of the Standard Grading Schedule for Grading Cities and Towns in the United States with reference to their fire defenses and physical conditions, after field inspection and test of the local facilities. The grading schedule is based on the premise that a community with no protection would have a deficiency grading of 5,000 points, while a perfect community would have a deficiency grading of zero points. The chief items that are taken into consideration are Water Supply, Fire Department, Fire Alarm System, Police, Building Laws, Fire Prevention and Structural Conditions. The maximum number of points chargeable to each of these items are as follows:

Water Supply	1,700
Fire Department	1,500
Fire Alarm System	550
Police	50
Building Laws	200
Fire Prevention	300
Structural Conditions	700
Total	5,000

"The quantity of water required for fire protection purposes in each community varies with the structural conditions which constitute the principal mercantile district or high value area and in average communities with normally anticipated structural conditions the required flow is determined by the formula:

$$G = 1020 \sqrt{P} (1 - .01 \sqrt{P})$$

where G equals gallons per minute, and P equals the population in thousands. The fire flow thus obtained for each community constitutes the basis for the grading schedule set up for that community in that most items in the schedule have a direct relationship to this feature of the supply. However, in all communities special conditions such as extensive flammable liquid storage or hazardous manufacturing activities may demand greater quantities of water in these special areas.

"Generally speaking, however, fire flow demand for principal mercantile districts or high value districts range from 1,000 g.p.m. for a period of four hours for a normal community of 1,000, to 12,000 gpm for a period of ten hours for a normal community with a population of 200,000. The required fire flow in residential districts depends upon the character and congestion of the buildings. Sections where structures are small and of low height, with about one-third of the lots in the block improved with buildings, require not less than 500 gpm. With larger or higher buildings, up to 1,000 gpm. is required, and where the district is closely built on, with buildings approaching the dimensions of hotels or high value residences, 1,500 to 3,000 gpm. is required, with up to 6,000 gpm. necessary in densely built sections of three stories and higher.

"These requirements merit some explanation, however, in that they indicate the quantity of water which authorities believe should be available in these respective districts, but it being recognized that lesser quantities are of appreciable value in fire fighting, the general practice is to accept for recognition for the establishment of a protected area, all hydrants which can be depended upon to deliver a minimum of 200 gpm. for a period of one hour. Hydrants meeting this requirement entitle the communities in question to a protected rate for all properties within 500 feet.

"Careful consideration in all cases should be given to hydrant spacing because the value and capacity of the water system is entirely dependent on the availability of the fire hydrants. In general, hydrants should be spaced so as to serve maximum areas of 40,000 to 120,000 square feet, depending on the structural conditions in the particular area. These area requirements, however, may be modified in residential districts consisting of single streets or rural roads without block development where buildings are normally on 100-foot lots, to provide a coverage of 120,000 square feet per hydrant by considering a width of protection of 200 feet and a spacing of 600 feet.

"In setting up municipal grading schedules the first consideration is given to the 'limiting factor' of the water system in that it is readily recognized that a hydrant or a system of hydrants might deliver from 1,000 to 5,000 gpm. whereas the capacity of the system over and above the consumption demands for a period of hours might be restricted by a supply works capable of delivering, for instance, only 500 gallons per minute, offset to only a slight extent by storage of 100,000 to 300,000 gallons, in which case the delivery of hydrants would indicate the limiting factor of the system. In other instances the capacity of the supply mains from the source of supply might be such that the initial flow at hydrants due to proximity of storage could not be maintained, or in other instances pumping equipment could be of such capacity as to be unable to maintain the initial hydrant delivery after depletion of storage. All of these features are studied and analyzed by the rating organization engineer during the survey and before proceeding with the grading schedule makeup."

*Presented before the Northeastern Water Works Co. Group Meeting in Camden, N.J.

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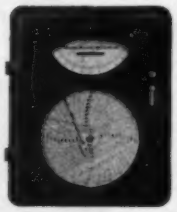
TYPE H METER



Operates in conjunction with Venturi tubes, flow nozzles, or orifice plates on differential heads of 64 inches and 114 inches of water. Measures over respective ranges of 10 to 1 and 13 to 1 within ± 2%. Wall bracket, panel mounting or floor stand, as desired. For measurement of water, air, sewage, sludge and industrial liquors. Instrument utilizes evenly spaced circular charts.

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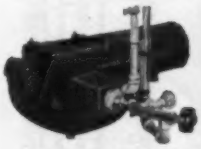

"S" PARABOLIC FLUME

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STORAGE ON THE DISTRIBUTION SYSTEM*

BY CHARLES B. BURDICK

Cons. Engr., Alvord, Burdick & Howson
Chicago, Ill.

IT HAS been aptly said that elevated storage is like money in the bank. It represents work already accomplished and an asset that can be drawn upon for instant use when needed.

Unlike storage on any other part of the water works system, storage on the distribution system is actually beneficial to every part of the water works, extending all the way back to the source of supply, through feeder pipes, pumps, treatment facilities and, in many cases, the water development facilities.

Like money in the bank, wherein only a certain amount is necessary for day to day commercial transactions, enough is enough. Money invested in excessive storage would better be devoted to something more needed. It is the present purpose to show how much storage may be warranted under general conditions and the available means for accomplishing it, bearing in mind that no two cases are exactly alike and that while the conditions surrounding most water works are similar, there are wide variations in conditions affecting certain cases. Therefore each case should have separate study if the project is to be both technically and economically sound.

Generally speaking, that water works system is the best that provides facilities adequate to meet all conditions of service, including rare emergencies, at the least cost. The latter takes into consideration expenses of operation balanced against capital costs, usually represented by interest and depreciation upon the investment.

Storage upon the distribution system is of principal value in the form of adequacy and reliability of service, and in its economy. It is justified to the extent that it increases more constancy of pressures and greater reliability and economy, bearing in mind that in practically all installations allowance must be made for the probable service requirements for a reasonable period in the future. Both reliability and economy are promoted by the effects of storage in securing more economical pumpage, and in providing an assured pressure and adequate volume of water for fire protection.

*A basic discussion of this important topic prepared especially for the Reference and Data Number of *Water & Sewage Works* at our request.—The Editors.

Conditions Affecting Storage

Every water works man would have his problem much simplified, and the investment in water works would be much reduced, if water could be served at a uniform rate of delivery throughout the year. This is impossible, however. The consumer properly demands water when he needs it, and needs vary widely with the seasonal extremes and wide variations in demand throughout the hours of the day.

Storage is particularly beneficial in the afternoon or evening hours upon a few days in exceptionally hot and dry summers. Such summers do not come every year, and therefore excessive demand often comes as a surprise. An examination of many pumping records indicates that the demands of one summer in five or ten may greatly exceed the ordinary summer. Therefore, in providing facilities for storage it

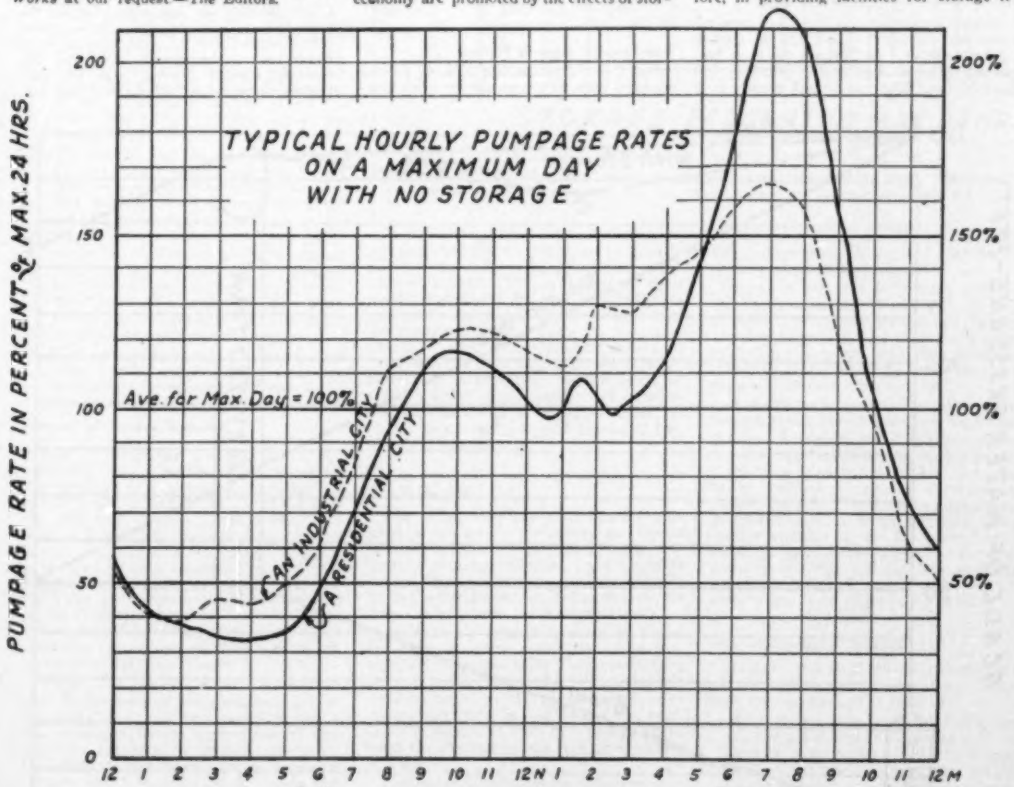


Fig. 1.—Range of Hourly Pumpage Rates on Maximum Days—Typical of Cities Without Distribution Storage. (Pattern for residential city compared with industrial city.)

is wise to allow a liberal percentage above average requirements in providing storage facilities.

The accompanying Table I is an analysis of the service requirements on five water works systems in cities varying from 37,000 to 320,000 population during years that are known to represent a well defined maximum in each city.

In these statistics the hourly pumpage rates were studied and correction was made for a small amount of elevated storage in several cases so that the figures would represent pumpage necessary to supply demand without storage. Fig. 1 shows diagrammatically the hourly rates of pumpage upon a maximum day for two cities, which represent common maximum and minimum conditions as to pumpage variation. There are some very large cities where use is more uniform. For more ready comparison, the pumpage rates have been expressed in percentage of the average pumpage rate (total pumpage) during the 24 hours of a maximum day. With information similar to this for any city, it is possible to compute the amount of storage which if most effectively liberated would make it possible to operate the pumps at a uniform rate throughout the 24 hours of a maximum day. In other instances, notably the small municipality, adequate storage can sometimes make possible the complete pumping requirement during the period of money-saving off-peak power rates.

Hourly variations in pumpage depend upon the character of the city in regard to similarity of use. Perhaps the most important consideration is the extent of industrial use. This can be and usually is a more or less uniform use. Upon the other hand, residential consumers use little or no water at night and make heavy demands at certain hours of the day, particularly during the early evening hours; and to this is added a very exceptional demand for lawn sprinkling on hot summer days. Recently, water used in cooling systems has placed an added burden on hot weather peak hours. In most cities the varying residential demand is more or less ironed out by commercial and industrial uses, and the extent of commercial and industrial use is probably largely accountable for differences in pumpage rates when comparing cities.

TABLE 1
Variations in Pumpage in Five Cities

Character of City	1 Residential	2 Industrial	3 Residential	4 Residential	5 Industrial
Population	37,366	100,426	110,468	307,000	320,000
Ave. pumpage MGD.	3.69	9.61	6.94	17.50	43.80
Gals. per capita	99	96	63	57	137
Max. 24 hrs. MGD.	5.09	17.42	13.66	30.65	70.20
Gals. per capita	136	174	124	100	220
Per cent of ave. day	138%	182%	196%	175%	160%
Max. hr. MGD.	8.05	35.80	20.36	53.00	115.70
Gals. per capita	216	358	278	174	360
Per cent of max. 24 hrs.	158%	205%	222%	172%	165%
Storage to Equalize Hour Peaks					
In gals. per capita	24	33	31	14	50
In % of max. 24 hrs.	18%	19%	25%	14%	23%
Reduced Pumpage Peak by Storage in—					
Gals. per capita	90	184	154	73	140
Per cent of max. 24 hrs.	37%	51%	85%	42%	39%

How Storage Improves Pressure

Fig. 2 is a cross section showing ground occupied by a city, and certain lines illustrating available water pressure created by a pumping station.

The line AB illustrates the drop in pressure in a case where no elevated storage exists, and pump pressure is so used up in deficient pipes that no pressure remains at the peak hour of the heaviest pumpage (demand) day at the remote end of the town.

With an elevated tank installed the pressure conditions are changed as follows upon a similar heavy pumpage day. Assume the storage is such that the pumps instead of running at a variable rate run a constant rate day and night. During the peak hour of use pressure will be represented by the line AC representing water flowing from the pumps. The line DC represents water flowing from the tank toward the pumping station, and line DE.

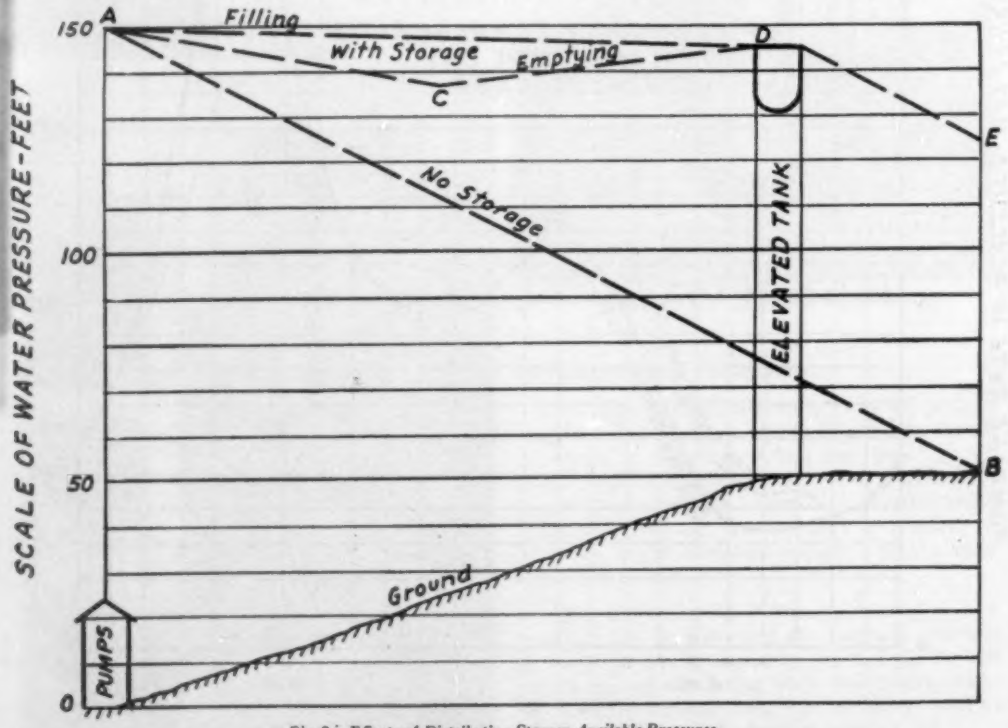


Fig. 2.—Effects of Distribution Storage Available Pressures (Shown for a maximum demand day.)

flowing from the tank away from the pumping station. The pressure losses at points between tank and pumping station are smaller than before because this district is being fed from two ends. This results in shorter travel, smaller velocities and greatly reduced friction losses. At points beyond the tank friction losses are the same as before but pressure is increased because the water is coming from the tank at a high elevation.

The conditions noted prevail approximately during the peak hours when use exceeds pumpage. After the peak is past and pumpage exceeds use, during night hours, the pressure approaches the line AD which represents conditions just as the tank is filled. The lines AC, DC and DE will be lower as the tank is depleted; and when an empty tank begins to fill the line AD will be much steeper.

The above illustrates the general result when storage is added without increasing the distribution feeders. Storage is an alternative to new and larger pipes and pumps.

Location and Height

A number of local conditions enter into the question of the best location for storage and the most suitable elevation. Storage is almost always an addition to an existing plant and therefore it must fit existing facilities as well as possible. The following general principles should be guides:

1—Storage should be reasonably close to heavy peak drafts of water and on the opposite side of such points from the pumping station.

2—Elevated storage at the pumps helps the pumps but does not add to the capacity of the distribution system, which involves more than half the cost of the average water works.

3—Elevated storage on the opposite side of heavy draft permits water to be fed from both ends of the distribution system, thus nearly or quite doubling the capacity of the feeders.

4—The top of the stored water will necessarily be slightly below the maximum existing pressure plane of the pumps; but must *not* be too high to fill in the night hours of a peak day. The depth should be as shallow as reasonably possible; 20 to 25 feet is common.

5—The value of storage is largely lost when too far away. Costly pipes can overbalance the advantage of storage.

Amount of Storage Required

Fig. 3 shows the amount of storage necessary upon a maximum day to reduce the pumpage to a constant rate throughout the 24 hours of such a day. It also shows the effect of various lesser amounts of storage in reducing the peak hour requirement. The curve shown on the diagram is a median line between the extremes represented by dots upon the diagram. Each dot represents a computation for one of the five cities shown in Table I. It will be observed that a large benefit in pumpage reduction can be secured from a relatively small installation in storage.

These data indicate upon the average that 20 per cent of the maximum day in elevated storage may be expected to reduce the maximum hourly peak about 45 per cent. Or, expressed in another way, in the five cities studied 30 gallons per capita in storage might be expected to reduce the maximum hourly pumpage peak rate 126 gallons per capita if the storage is most effectively used.

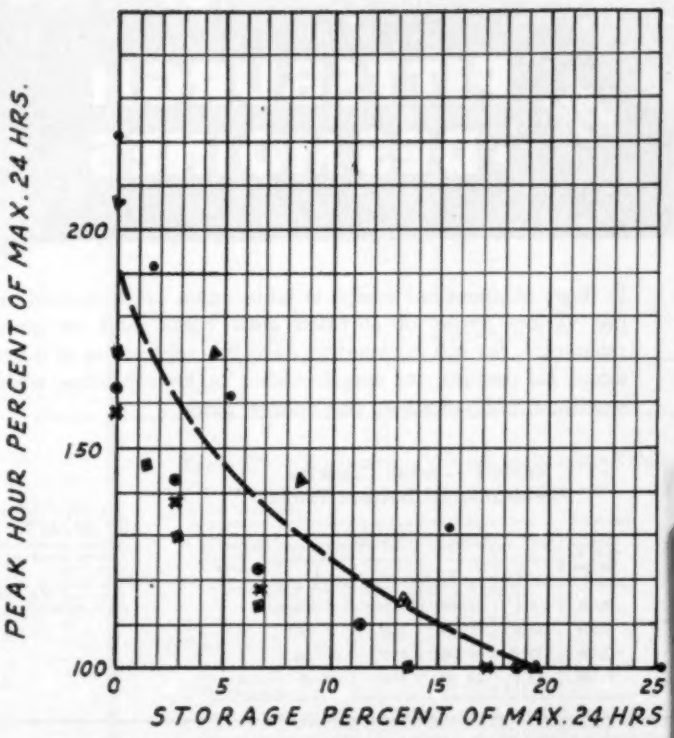


Fig. 3.—Effects of Storage on Pumpage Peaks in Five Cities
(Expressed in per cent of max. 24 hr. pumpage on maximum demand days. Each symbol of different design represents one of the five cities covered in Table I.)

In determining how much elevated storage shall be built, consideration is properly given to the existing installations in water supply facilities. The system as a whole must be designed for the maximum requirements for water, which must include the maximum requirements for fire protection if good fire protection service is furnished. In each case a proper installation is a coordination between elevated storage, water supply, pumps and distribution pipe facilities, so adjusting these facilities means that adequate service is furnished at least cost.

Fire Protection

One of the most important benefits from elevated storage is the ability to respond instantly to the heavy draft of water required for fire protection. In the smaller towns this furnishes an especially valuable service while pumps are being started, for many such systems pump intermittently.

In Table 2, column 4, there is shown the rates at which water should be furnished to comply with recommendations of the National Board of Fire Underwriters for cities of various sizes. For comparison there is also shown the average and maximum rates of pumpage based upon the average of the five cities shown in Table 1.

For the smallest town the fire demand is nearly five times the peak hour use, and pumps and distribution system must be designed accordingly without storage, bearing in mind that about 50 per cent above the average domestic demand plus the fire demand must be accommodated.

In towns over 25,000 the peak hour and the fire demand are about equal. In cities of 100,000 or more the combined domestic and fire demand is less than the domestic peak hour demand, and fire protection ceases to be a controlling factor so far as rates of pumpage are concerned.

It should be borne in mind that adequate fire protection provides for very rare emergencies. Likewise, the maximum storage for domestic peak hours is needed on only a few days in exceptional years, and usually an installation contains a reserve for future growth. Therefore an installation proportioned for domestic service is an important addition to the fire protection. It alone provides ample water for the great majority of fires, and the first and more important water in exceptional fires. Its great value is its readiness to serve.

Types of Distribution Storage

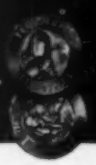
Various types of distribution storage are best adapted to special conditions. These types are summarized as follows:

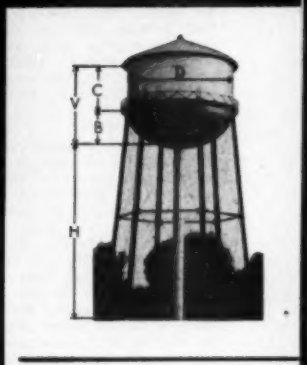
1—Most of the cities in this country are relatively flat and the elevated tank of steel is most widely used. It is now built in shallow depths so that all the water is stored at sufficient elevation to be useful. Sizes as large as 2 mg. are available. Recent designs present a very pleasing appearance.

(*Continued on page* 46)

Capacities and Sizes OF STANDARD ELEVATED

by PITTSBURGH • DES MOINES





In these compact but complete tables, data are furnished on the various types of elevated steel tanks, and on steel reservoirs. For full information as to the application of these tanks, for designs, for specifications, or for estimates, write —without obligation—to our nearest office.

Table I — Small Capacity Hemispherical Bottom Tanks

Capacity in U. S. Gallons	TANK DIMENSIONS				Number of Columns
	D	V	B	C*	
5,000	9' 0"	11' 0⅜"	1' 2½"	9' 9⅜"†	4
10,000	13' 0"	11' 7⅜"	6' 0"	5' 7⅜"	4
15,000	13' 0"	16' 10¾"	6' 0"	10' 10¾"	4
20,000	13' 0"	21' 8"	6' 0"	15' 8"	4

*This column lists height of the tank cylinder up to the high water line. The cylinder actually extends 3 inches above the high water line.

†The bottom of this 5,000 gallon tank is a sector of a 9 ft. radius sphere.

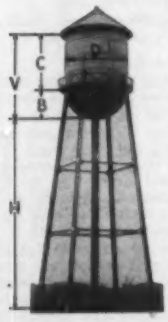


Table II — Standard Hemispherical Bottom Tanks

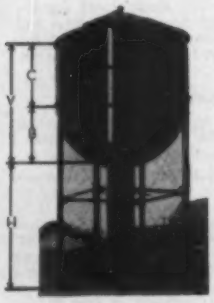
Capacity in U. S. Gallons	TANK DIMENSIONS				Number of Columns
	D	V	B	C*	
25,000	15' 0"	19' 10½"	5' 4"	14' 6½"	4
30,000	15' 0"	23' 8½"	5' 4"	18' 4½"	4
40,000	17' 0"	24' 11¾"	6' 8"	18' 3¾"	4
50,000	19' 0"	25' 6"	8' 0"	17' 6"	4
60,000	19' 0"	30' 3¾"	8' 0"	22' 3¾"	4
75,000	21' 0"	30' 6¾"	8' 0"	22' 6¾"	4
100,000	24' 0"	30' 11¾"	8' 6"	22' 5¾"	4
150,000	28' 0"	34' 5½"	10' 5"	24' 0½"	4
200,000	32' 0"	35' 11½"	12' 9"	23' 2½"	6

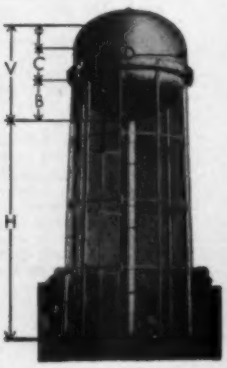
* This column lists height of the tank cylinder up to the high water line. The cylinder actually extends 3 inches above the high water line.

Table III — Railroad Type Hemispherical Bottom Tanks

Capacity in U. S. Gallons	TANK DIMENSIONS				Number of Columns
	D	V	B	C*	
25,000	15' 0"	19' 7½"	5' 4"	14' 3½"	4
30,000	17' 0"	18' 8½"	6' 5"	12' 3½"	4
40,000	19' 0"	20' 2¾"	7' 5"	12' 9¾"	4
50,000	21' 0"	20' 9¼"	8' 0"	12' 9¼"	4
60,000	24' 0"	19' 11½"	10' 2"	9' 9½"	4
75,000	24' 0"	23' 6¼"	8' 9"	14' 9¼"	4
100,000	28' 0"	23' 3½"	10' 2"	13' 1½"	4
150,000	28' 0"	34' 5½"	10' 5"	24' 0½"	4
200,000	36' 0"	28' 11"	14' 1"	14' 10"	6

* This column lists height of tank cylinder up to the high water line. The cylinder actually extends 3 inches above the high water line.





STEEL TANKS

Table IV
Hemi-ellipsoidal Bottom Tanks

Capacity in U. S. Gallons	TANK DIMENSIONS				Number of Columns
	D	V	B	C*	
25,000	17' 0"	15' 1½"	3' 8"	11' 5½"	4
30,000	17' 0"	18' 2½"	3' 11"	14' 3½"	4
40,000	21' 0"	16' 6"	5' 6"	11' 0"	4
50,000	22' 0"	18' 8¾"	5' 10"	12' 10¾"	4
60,000	24' 0"	19' 1"	6' 6"	12' 7"	4
75,000	26' 0"	20' 5¼"	7' 2"	13' 3¼"	4
100,000	28' 0"	22' 11"	7' 0"	15' 11"	4
150,000	34' 0"	24' 10"	10' 2"	14' 8"	6
200,000	38' 0"	26' 10"	11' 7"	15' 3"	6

* This column lists height of tank cylinder up to the high water line. The cylinder actually extends 3 inches above the high water line.

Table V — Double Ellipsoidal Tanks

Capacity in U. S. Gallons	TANK DIMENSIONS					Number of Columns
	D	V	B	C	T	
50,000	22' 0"	19' 8"	5' 10"	9' 4"	4' 4"	4
60,000	24' 0"	19' 7"	6' 4"	8' 7"	4' 8"	4
75,000	26' 0"	21' 0"	7' 0"	9' 0"	5' 0"	4
100,000	28' 0"	23' 8"	7' 0"	11' 1"	5' 7"	4
100,000	30' 6"	22' 0"	7' 3"	8' 4"	6' 5"	4
125,000	32' 0"	23' 4"	8' 8"	8' 8"	6' 0"	4
150,000	34' 0"	25' 0"	9' 4"	8' 10"	6' 10"	4 or 6
200,000	36' 0"	28' 8"	9' 0"	12' 11"	6' 9"	6
250,000	40' 0"	29' 5"	10' 4"	11' 7"	7' 6"	6
300,000	42' 0"	31' 7"	10' 9"	13' 10"	7' 0"	6
400,000	48' 0"	35' 7"	12' 2"	14' 9"	8' 8"	6 or 8
500,000	50' 0"	39' 2"	13' 0"	14' 6"	9' 8"	8 or 10
750,000	60' 0"	40' 0"	15' 11"	12' 7"	11' 6"	10
1,000,000	65' 0"	48' 5"	21' 8"	15' 9"	11' 9"	10 or 12
1,000,000	68' 0"	42' 0"	18' 3"	11' 0"	12' 9"	10 or 12

Table VI—Hemi-Ellipsoidal Bottom Dome Roof Welded Elevated Tanks

Capacity U. S. Gallons	TANK DIMENSIONS			
	D	V	B	C*
25,000	18' 0"	14' 0⅛"	4' 9"	9' 3⅛"
30,000	18' 0"	16' 7⅛"	4' 9"	11' 10⅛"
40,000	20' 0"	17' 10⅜"	5' 2⅜"	12' 8⅛"
50,000	22' 0"	18' 9"	5' 11"	12' 10"
60,000	24' 0"	19' 1⅛"	6' 4⅛"	12' 9"
75,000	26' 0"	20' 3⅜"	6' 10⅛"	13' 5⅛"
100,000	28' 0"	23' 3⅜"	8' 7"	14' 8⅜"
150,000	32' 0"	26' 9⅛"	9' 4⅛"	17' 5"

*This column lists height of tank cylinder up to the high water line. The cylinder actually extends 3 inches above the high water line.

Table VII — Double Ellipsoidal Welded Elevated Tanks

Capacity U. S. Gallons	TANK DIMENSIONS				
	D	V	B	C	T
25,000	18' 0"	14' 4⅜"	4' 9"	6' 0⅛"	3' 7⅛"
30,000	18' 0"	17' 0"	4' 9"	8' 7⅛"	3' 7⅛"
40,000	20' 0"	18' 6⅜"	5' 2⅜"	9' 4⅛"	4' 0"
50,000	22' 0"	19' 2½"	5' 11"	8' 10⅜"	4' 4⅜"
60,000	24' 0"	19' 7½"	6' 4⅛"	8' 5⅜"	4' 9⅜"
75,000	26' 0"	21' 2⅛"	6' 10⅛"	9' 1¼"	5' 2⅜"
100,000	28' 0"	23' 8¾"	8' 7"	9' 6½"	5' 7½"
150,000	32' 0"	27' 4"	9' 4⅛"	11' 2⅜"	6' 4½"
200,000	36' 0"	29' 4⅜"	10' 6⅛"	11' 7⅛"	7' 2⅜"
250,000	38' 0"	33' 0"	11' 3⅜"	14' 3⅜"	7' 4½"
300,000	44' 0"	30' 9"	13' 0½"	7' 11⅞"	9' 8½"
400,000	48' 0"	34' 3⅜"	14' 7"	11' 0"	8' 8½"
500,000	50' 0"	39' 0⅜"	15' 6⅜"	15' 5½"	8' 0⅜"
600,000	50' 0"	48' 10½"	15' 6⅜"	22' 3¼"	8' 0⅜"
750,000	60' 0"	41' 7⅜"	18' 0"	11' 10⅜"	11' 9"
1,000,000	65' 0"	47' 1⅛"	20' 1⅜"	16' 5⅜"	10' 5½"
1,250,000	70' 0"	51' 2⅜"	23' 0"	19' 5⅜"	8' 9"
1,500,000	70' 0"	58' 10⅜"	23' 0"	28' 1⅜"	8' 9"

Table VIII — Low Head Range Tanks having Shallow Supported or Combination Suspended and Supported Bottoms

(a) These tanks are available in the following types:

Toroidal Bottom Tanks with Dome Roofs.
Toroidal Bottom Tanks with Ellipsoidal Roofs.
Toro-segmental Bottom Tanks with Ellipsoidal Roofs.
Obloidal Tanks.
Multi-cone Bottom Tanks.
Lo-head Tanks.

(b) One or more of these types are available in the following sizes:

500,000 U. S. Gallons.
750,000 U. S. Gallons.
1,000,000 U. S. Gallons.
1,250,000 U. S. Gallons.
1,500,000 U. S. Gallons.
2,000,000 U. S. Gallons.
2,500,000 U. S. Gallons.

(c) These tanks are built in standard head ranges of 25' 0", 30' 0" or 35' 0".

Table IX — Supporting Towers for Elevated Tanks

(a) Standard Heights:

The height of elevated tank structures is measured from the underside of the bases of the steel columns to the lower capacity level. The following are considered standard heights:

Up to 50 ft. by even 2-ft. intervals.
From 50 ft. to 100 ft. by even 5-ft. intervals.
Over 100 ft. by even 10-ft. intervals.

(b) Tower Types:

Structural, latticed column.
Structural, H column.
Tubular column.

Generally speaking, columns in the tower of an elevated tank are inclined so that the column spread at the base is greater than at the top. This reduces the overturning effect of wind, which makes for economy in the tower itself and in the foundations. For low towers, however, where the overturning force of wind is not so great, the columns may be vertical; and for large capacity, large diameter tanks, particularly where tubular columns are selected, the tower columns may be vertical.

Table X — Steel Reservoirs

Capacity in U. S. Gallons	Diameter	Height
50,000	20'	21' 6"
60,000	22'	21' 6"
75,000	24'	22' 6"
100,000	26'	25' 6"
150,000	30'	28' 9"
200,000	34'	29' 9"
250,000	38'	29' 9"
300,000	42'	29' 3"
400,000	46'	32' 6"
500,000	50'	34' 6"
750,000	60'	35' 9"
1,000,000	70'	35' 0"
1,500,000	80'	40' 3"
2,000,000	95'	38' 3"
2,500,000	110'	35' 6"
3,000,000	120'	35' 9"
4,000,000	130'	40' 9"

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TABLE 2
Rates of Pumpage Required in Cities of Various Sizes

Population	1 Ave. MGD. at 100 Gals. per Capita 100%	2 Probable Peak 24 Hrs. MGD. 167%	3 Probable Peak Hr. MGD. 308%	4 Max. Rate for Fire Protection MGD.	5 Storage for Hourly Peaks 20% of Max. Day
1,000	.1	.17	.31	1.41	.033
2,000	.2	.33	.61	2.15	.066
4,000	.4	.67	1.24	2.86	.134
10,000	1.0	1.67	3.08	4.30	.334
28,000	2.8	4.66	8.64	7.15	.932
60,000	6.0	10.00	18.50	10.00	2.00
100,000	10.0	16.70	30.80	12.90	3.34
200,000	20.0	33.40	61.60	17.20	6.68

2—There are some situations where elevated ground is available but not high enough for a concrete reservoir on the ground. In such situations circular steel tanks up to 40 to 60 ft. high and of large capacity can be built for less than half the cost of elevated tanks per unit of capacity. Such tanks can sometimes be scattered at more than one location with beneficial results. For the higher of such tanks all the water may not be fully useful but it furnishes a cheap support for the more useful elevated water.

3—Many cities are so fortunate as to have elevated ground sufficiently high to accommodate elevated reservoirs. These cost about half as much as most elevated tanks. Most recent reservoirs are covered, built of reinforced concrete buried in the ground, and have long life with small maintenance costs. Reasonable cost favors large capacities. In some installations the entire fire protection water is stored in addition to domestic requirements. As much as 100 to 300 gallons per capita is stored in some cities.

4—Where elevated ground is not available it is sometimes economical to build concrete reservoirs or steel tanks on the ground, fill them at night with water bled from the mains and repump stored water back into the mains by remote controlled or automatically controlled electric pumps. The capitalized cost of repumping should, of course, be charged to the installation. In cost comparisons such pumping may be less costly than might be thought if operation is required only a few hours per day during a limited portion of the year.

Operation of Storage

Money should be conserved for use. Likewise water stored should be conserved so that it will be available when needed. There is little use for storage during about 80 per cent of the normal year. With storage it becomes possible to run pumps at a nearly uniform rate, with attendant advantages of economy, and on normal days to utilize only a few feet of the upper part of the storage. The storage should only be materially exhausted during the peak hours of the heavy pumpage days, and always refilled before morning.

Water works men are now more firm than ever in the belief that storage on the distribution system pays its way in the reliability and economy of water service.

FIRE HYDRANT FLOW GAGE

By A. A. HIRSCH*
State Dept. of Education, Baton Rouge, La.

Of the several methods in vogue for hydrant flow measurement, namely the special pitot tube-gage combination, the stream trajectory, the short tube with terminal orifice, and the velocity head reading by means of a pressure gage on a closed cap, the last named is the one most generally employed by reason of its simplicity in principal and equipment.

The Procedure

In determining flow from a fire hydrant by the pressure gage method all that is needed is to connect an accurate gage to the closed nozzle, and discharge the hydrant through the other nozzle. The flowing nozzle may be considered as a "short-tube"

Figure 1.—Dial of pressure gage calibrated to read directly fire hydrant flow from a 2½-inch nozzle.

and its flow calculated from the usual orifice formula, but using an orifice coefficient of 0.9 instead of the familiar 0.61 which holds for a sharp edged orifice. Thus

Flow (cu. ft./sec.) = C A V where C = fire hydrant orifice coefficient = 0.9.

$$A = \text{area of nozzle (sq. ft.)} = 0.785 \times \frac{\text{Diameter}^2_{\text{(inches)}}}{144} = 0.00545\ \text{Diameter}^2_{\text{(inches)}}$$

$$V = \sqrt{2\,g\,h_{\text{ft. water}}} = \sqrt{2 \times 32.16 \times 2.31 \times \text{Pressure}_{\text{psi.}}}$$ the pressure reading being taken off the closed nozzle

$$= 12.2\sqrt{\text{Pressure}_{\text{psi.}}}$$

Substituting in the first equation:

$$\text{Flow (gpm.)} = 7.48 \times 60 \times 0.9 \times 0.00545 \times \text{Diameter}^2 \times 12.2\sqrt{\text{Pressure}_{\text{psi.}}}$$

$$= 27\ \text{Diameter}^2_{\text{(inches)}}\sqrt{\text{Pressure}_{\text{psi.}}}$$

This is the familiar form commonly used to calculate the discharge from a fire hydrant.

Ordinarily the 2½-inch nozzle is used, as the 4- or 4½-inch nozzles do not conform with accuracy to a simple formula. Substituting the value of 2½ inches for the diameter in the above formula there results

$$\text{Flow (gpm. through 2½ in. nozzle)} = 27 \times 2.5^2 \times \sqrt{\text{Pressure}_{\text{psi.}}} = 168.7\sqrt{\text{Pressure}_{\text{psi.}}}$$

from which the discharge through a 2½-inch hydrant nozzle may be conveniently calculated.

The Self-Calculating Gage

Inasmuch as a given velocity head on the pressure gage corresponds to a fixed discharge the gage may be calibrated to read this flow directly and thereby obviate the need for calculation. A dial so calibrated is illustrated in Fig. 1. By marking off a dial in this manner the gage may be used in hydrant flow studies to facilitate discharge adjustments and to enable flow evaluation on the spot without calculations or conversions. Fig. 1 may also be used as an approximate solution to the hydrant formula for a 2½-inch nozzle rather than perform the numerical substitutions.

The accuracy of the pressure gage should be checked on a cold test apparatus, especially in the low pressure range below 500 gpm. where slight inaccuracy causes relatively large errors in the indicated discharge. If the test gage is off the needle position may be reset, the linkage between hollow spring and sector adjusted as required, or a calibration curve drawn to show the true pressure corresponding to any gage reading. From Fig. 1 it will be noted that below a flow of about 250 gpm. the type of pressure gage as illustrated is inapplicable since it fails to deflect.

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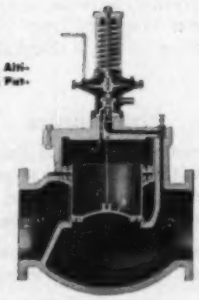

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The Belt Driven unit is a sturdy, dependable unit for use where electric power is not available or where operation is to be synchronized with pumping equipment driven by gasoline engine or other similar motive power.

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CONVENIENCE

W&T is represented in each of the 35 cities listed above by chlorination specialists to assist in selecting proper equipment for any chlorination problem. Their recommendations involve no obligation.

Current literature on the many phases of chlorination, ammoniation and dry chemical feeding is available on request.

MAINTAINING TRANSMISSION LINE CAPACITY WITH CHLORINE-AMMONIA

15 Years' Use Proves Value In Maintaining High Flow Rates at Moderate Cost

LAURENCE J. GRISWOLD
Engineer
Water Supply Board, Utica, N.Y.

IN December, 1933, chlorine-ammonia equipment was installed at the reservoir end of a 24-inch cast iron transmission main, furnishing the City of Utica with its principal source of water supply.

The primary purpose of this installation was to prevent or retard, if possible, the loss of carrying capacity, which occurred in a comparatively short time, after each mechanical cleaning of the twelve-mile line.

The first report on what was then considered a worthwhile experiment was given before the American Water Works Association in 1934 by Hodges and Ackerman[1], after about nine months of use and observation. In April, 1936, and again in 1937 the original data, brought up to date, was reported in *Water Works and Sewerage* (now *Water & Sewage Works*), in each case with continued encouraging results, but still after too short a period for any final conclusions.

Use Proves Value

Now after fifteen years of continuous use of chloramines on this pipe line, with frequent checks as to pipe line condition, some definite conclusions can be drawn. (a) This treatment process does maintain carrying capacity with but slight loss over long periods of time when used on waters of a certain type[1]. (b) While the original reports on the use of chloramines at Utica stressed the prevention of tuberculation, it now appears from a study of all of the Utica data and the reports of others[2][3] that the elimination of bacterial slime growth on the interior of the pipe is probably of equal importance with the prevention of tuberculation in maintaining high pipe line carrying capacity. (c) An application ratio of ammonia to chlorine of 1:5-6, with a residual of 1 to 1.5 ppm. at the end of the twelve-mile 24-inch unlined cast iron pipe line, has been effective in maintaining the carrying capacity of the line with an average loss in the Hazen-Williams "C" value of only ten points in seven years.

The bacterial aspects of the formation of tubercles and slime in water mains have been reported in the technical press and journals. Excellent papers by Reddick and Linderman[4], Committee Report[5], Wilson[6], and Storkey[7], quite adequately cover this phase of the subject.

The writer believes that the economics of the application of the chlorine-ammonia or the superchlorination treatment in its relation to increased water supply is of sufficient general interest and importance to merit a somewhat detailed study and report on the results achieved at Utica.

Data on Operation

The statistical and chronological data covering the transmission line are shown in Table A for ready comparison and reference. A paper, presented before the New England Water Works Association in 1924[8] by Frederic E. Beck, (then Chief Engineer of the Utica Water System) on the "Increase of Available Water Supply with No Capital Investment" reported the success of a waste water survey and the first mechanical cleaning of the 24-inch line. (Table A, line 2.) These operations were well worth reporting, since the increased supply made available thereby, had at least for the time being postponed an estimated $713,000 pipe line construction program, which was then considered necessary to keep supply ahead of demand.

To maintain a "C" value of not less than 100 after the first cleaning of the line in 1922, without the use of the chlorine-ammonia treatment, the line was cleaned on the average every 19.7 months. This frequent cleaning maintained an average daily flow for the period from October, 1922, to March, 1934, inclusive, of 11.3 mgd. or 2.5 mgd. more than the line was carrying in 1922 when it was first cleaned. It is to be noted here that the loss in carrying capacity during this period, when only cleaning was used to maintain high flow, did not take place at a uniform rate.

By plotting the Hazen-Williams "C" values obtained by pipe line measurements taken over a period of seven cleanings, it was possible to obtain an average curve showing the rate of loss of carrying capacity. From this curve could be computed the average flow for any period between cleanings, and the data so computed is the basis for Curve I, showing the average increase in water produced, plotted against frequency of cleaning. (See accompanying graph.)

The sharp loss in carrying capacity which takes place in the first few months after cleaning without the chloramine treatment can be accounted for only by the immediate and comparatively rapid regrowth of slime on the pipe interior, with the formation of tubercles the factor causing the slower loss of capacity over a longer period of time.

In the graph, data are plotted for the increased water produced and cost per million gallons of this water against frequency of cleaning.

Curves I and III are the quantity and cost curves respectively for the 24-inch line without the use of the chlorine-ammonia treatment. Curves II and IV are the quantity and cost curves respectively for the line with the chlorine-ammonia treatment. In the case of each pair of curves the data has been extended somewhat beyond the limit of actual experience by a reasonable extension of the plotted curves based on loss of "C" value.

With the two sets of curves plotted as shown, some interesting comparisons may be made as to costs and water produced. Unfortunately, data are not available for the same total periods of time for both sets of curves.

Cost Data

On Curve IV showing the cost per million gallons when using chloramines and cleaning, it will be noted that a minimum cost per mil. gal. of water produced is reached with a frequency of cleaning of every 5½ years. At that frequency of cleaning of the line, the average increased the flow was slightly over 5.1 mgd. (Curve II) at a cost of $2.40 per mil. gal. (Curve IV). At the same cost per mil. gal. without the use of chloramines (Curve III) it would have been necessary to clean the line about every seven months and the average increased flow would have been about 3.65 mgd. (Curve I).

A comparison of Curves I and II indicates a slightly greater effectiveness of cleaning when using chloramines. At the zero line it will be noted that the increased flow after cleaning was 5.5 mgd. when using chloramine, but only 5.3 mgd. without water treatment.

Since the loss in carrying capacity, when using chloramines as reflected in Curve II is very gradual, no very useful or extended

TABLE A

Statistical Data for Twelve Miles of 24-Inch Unlined Cast Iron Pipe at Utica, New York—1906-1948

	Date	Remarks	Months Since Last Cleaning	"C" Before	"C" After	Delivery mgd. (1) Before	Delivery mgd. (1) After
1.	June 1906	Line new	0	.....	135(a)	.....	13.6
2.	Oct. 5, 1922	Cleaned	196	88	Oct. '22 128	8.8	12.8
3.	Apr. 1, 1924	Cleaned	18	107	May '24 133	10.7	13.3
4.	Aug. 27, 1925	Cleaned	17	104	Oct. '25 139	10.4	13.9
5.	May 4, 1927	Cleaned	20	101	June '27 141	10.1	14.1
6.	Aug. 6, 1929	Cleaned	27	100	Sept. '29 139	10.0	13.9
7.	Dec. 23, 1930	Booster pump installed	17	107	107	10.7	11.7(c)
8.	Jan. 3, 1931	Cleaned(d)	17	107	Sept. '31 130	11.7 10.7	14.2 13.0
9.	June 16, 1933	Cleaned	29	104	July '33 134	11.3 10.4	14.6 13.4
10.	Dec. 13, 1933	Chlorine-Ammonia treatment started	6	.....	.....	.....	.....
11.	Apr. 8, 1934	Cleaned	10	109	Apr. '34 141	11.9 10.9	15.4 14.1
12.	June 21, 1941	Cleaned	87	130	July '41 145	14.2 13.0	15.8 14.5
13.	May 25, 1948	Cleaned	83	116	May '48 143	14.8 13.6	15.6 14.3

(a) Computed; Hazen-Williams formula for constant reservoir level or pumping head and actual pipe diameter of 24.2 inches.
(b) Conservative estimate for new coated C.I. pipe. (No measurement taken.)
(c) Shows effect of booster pump for increasing supply.
(d) Upper figures from Item 8 through 13 show delivery with booster pump; lower figures are for gravity flow.

comparisons may be made with Curve I showing the same data without chloramines. It is interesting to note, however, that with a frequency of cleaning of every nine years (Curve II), when using chloramine, the average increased flow over the period was about 4.8 mgd. at a cost of $2.45 per mil. gal.

For the same 4.8 mil. gal. average increase without chloramine it would have been necessary to clean the line about every one and one third months (obviously an impractical procedure) at a cost of about $9.80 per mil. gal. of increased supply.

Since the minimum rate for water in the Utica schedule is $68.19 per mil. gal., it would be profitable from an economic standpoint to clean the line monthly either with or without the use of chloramines, since the cost per mil. gal. to produce at this frequency of cleaning would be respectively $12.80 and $11.90.

Practical Considerations

From an operating standpoint it would not be practical to clean the line much more frequently than once each year. This practical consideration fortunately coincides with points on Cost Curves III and IV, where the curves have begun to flatten out.

Another practical consideration affecting the frequency of cleaning, and not taken into account in any of the curves, is the fact that no water is produced during the period covered by the cleaning operation.

If we assume that line cleaning or the combination of line cleaning and the use of chloramines would only be used to produce additional water needed for sale (a reasonable assumption) and compare the net profits from the sale of water produced by both methods we find that at a frequency of cleaning of one year the net profit per day using chloramines would be $351.64 as against $158.48 without the use of chloramines.

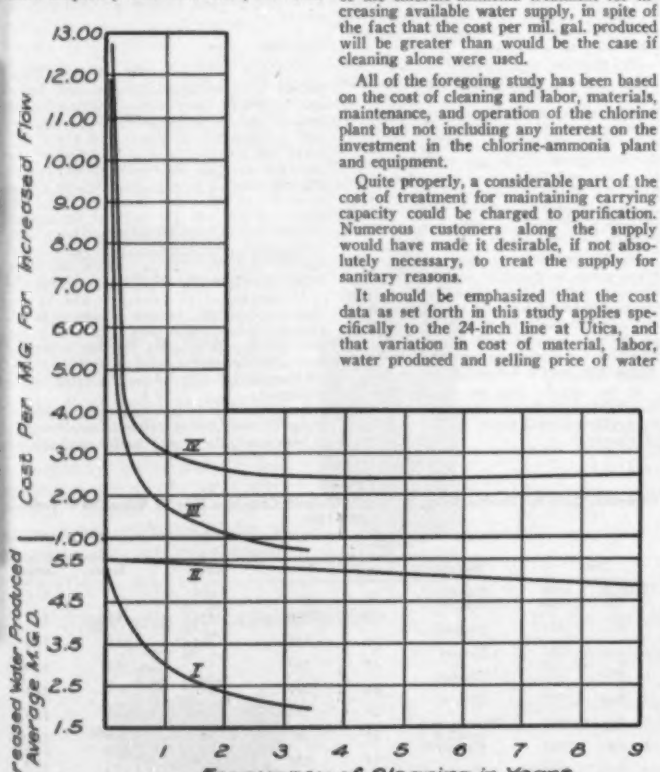
At a cleaning frequency of three years and five months (the last point on Curves I and III) the daily net profit with the use of chloramines would be $345.50 as against $130.17 without the use of chloramines.

The above comparisons quite effectively show the economic soundness of the use of the chlorine-ammonia treatment for increasing available water supply, in spite of the fact that the cost per mil. gal. produced will be greater than would be the case if cleaning alone were used.

All of the foregoing study has been based on the cost of cleaning and labor, materials, maintenance, and operation of the chlorine plant but not including any interest on the investment in the chlorine-ammonia plant and equipment.

Quite properly, a considerable part of the cost of treatment for maintaining carrying capacity could be charged to purification. Numerous customers along the supply would have made it desirable, if not absolutely necessary, to treat the supply for sanitary reasons.

It should be emphasized that the cost data as set forth in this study applies specifically to the 24-inch line at Utica, and that variation in cost of material, labor, water produced and selling price of water for any other line will give a different set of curves, although probably of the same general form. From the data presented, however, it is evident that the cost of using the chlorine-ammonia treatment could be much higher, the amount of water produced less, and the selling price of water lower within a considerable range and the treatment would still be economically sound as a means of producing additional water.



Comparative Data on Cost and Quantity of Water Produced With and Without Chlorine-Ammonia Treatment. (Curves I & III without chlorine-ammonia. Curves II & IV with chlorine-ammonia)

It will be noted that Item 7 in Table A records the installation of a booster pump at the head end of the 24-inch gravity line. By the use of this pump at the highest safe head possible, the line delivery was increased by one mil. gal., with the line in a partially dirty condition. The importance of clean pipe lines particularly at higher heads and velocities is indicated by Item 11, Table A, which shows that under gravity and pumping heads the line produced respectively 10.9 and 11.9 mgd. or a difference of 1 mgd. before cleaning. After cleaning, the line produced under gravity and pumping heads, respectively, 14.1 and 15.4 mgd. or a difference of 1.3 mgd.

How effectively the means set forth in this study, especially the chloramine treatment, have been in deferring the $713,000.00 construction program planned in 1924 may be judged by the fact that not until 1945-46, due to the war use, was it necessary to build any additional transmission line. At the present time an additional section of line is being built.

The expenditures on the 1945-46 and 1949 construction will total about $325,000.00, which is still less than half of that which it was estimated in 1924 would be necessary to expend to maintain supply. It is obvious, of course, that the direct comparison of current expenditures with 1924 estimates is a somewhat questionable procedure, but the comparison made in this way is still the more striking.

All of the recently laid transmission mains have been cement-lined pipe which will eliminate the possibility of tuberculation. However, since recent experiences with cement-lined pipe have demonstrated that cement lining does not necessarily prevent the formation of flow retarding slimes, it is planned to continue the chloramine treatment of the new lines.

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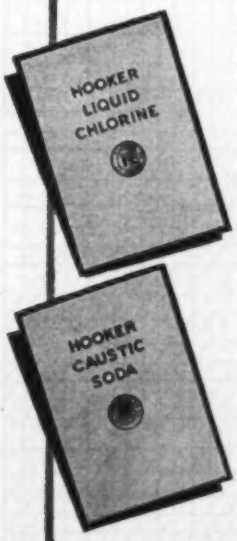

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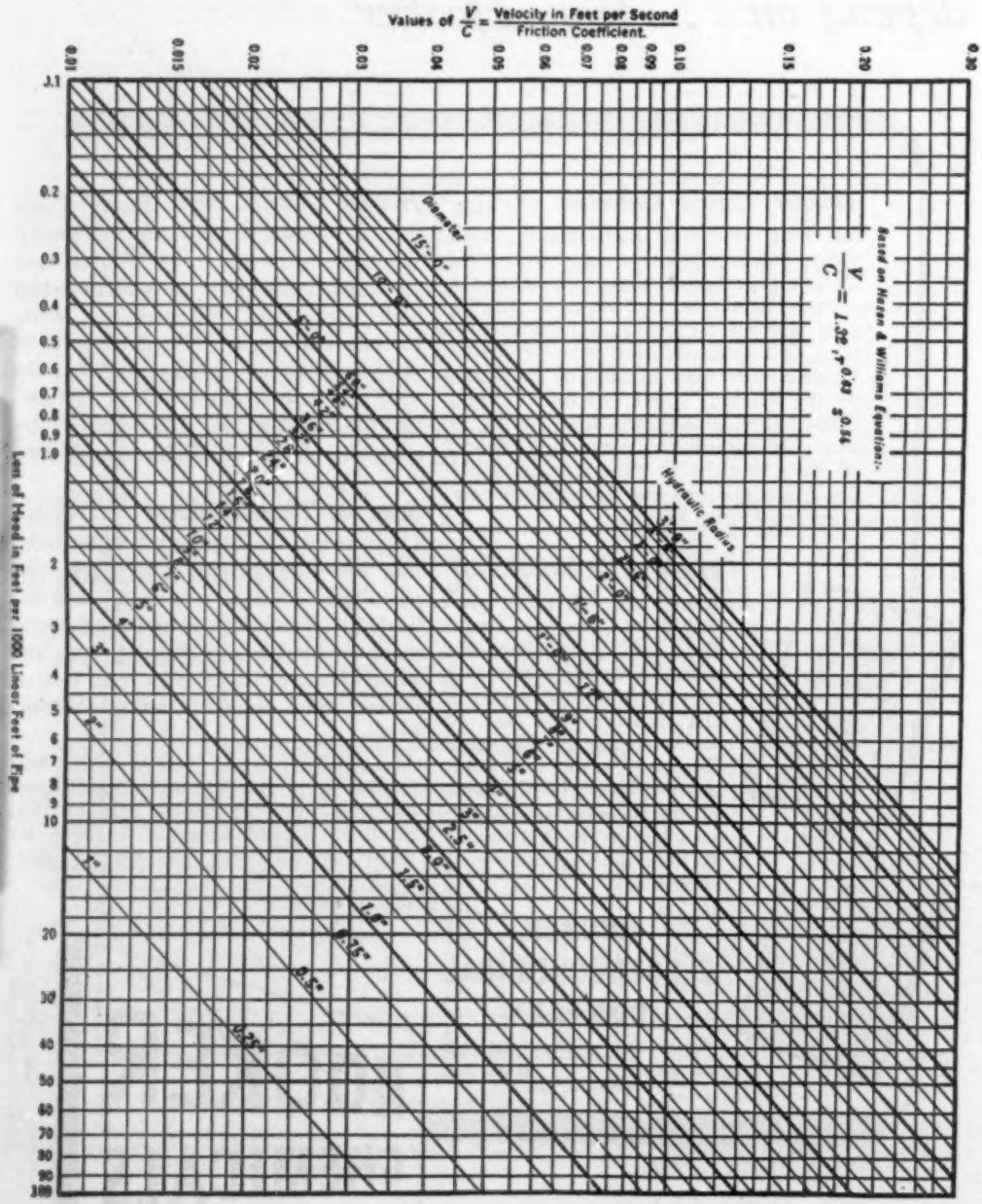
CHART OF LOSS OF HEAD IN FEET PER 1000 FT. OF PIPE



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FRICTION OF WATER PIPES

The pipe frictions shown in the following tables are taken by permission from the more complete copyright tables by Williams and Hazen, published by John Wiley & Sons, and these values are recommended for use in figuring pipe frictions.

Loss of Head in Feet Due to Friction, per 100 feet of 15 year old Ordinary Iron Pipe

U.S. Gal's per Min.	1" Pipe		1¼" Pipe		1½" Pipe		2" Pipe		2½" Pipe		3" Pipe	
	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.
10	3.72	11.7	2.14	3.05	1.57	1.43	1.02	0.50	0.66	0.17	0.45	0.07
15	5.60	25.0	3.2	6.50	2.36	3.0	1.53	1.0	0.98	0.36	0.68	0.15
20	7.44	42.0	4.29	11.1	3.15	5.2	2.04	1.82	1.31	0.61	0.91	0.25
25	9.30	64.0	5.36	16.6	3.94	7.8	2.55	2.73	1.63	0.92	1.13	0.38
30	11.15	89.0	6.43	23.5	4.72	11.0	3.06	3.84	1.96	1.29	1.36	0.54
35	13.02	119.0	7.51	31.2	5.51	14.7	3.57	5.1	2.29	1.72	1.59	0.71
40	14.88	152.0	8.58	40.0	6.3	18.8	4.08	6.6	2.61	2.20	1.82	0.91
45			9.65	50	7.08	23.2	4.60	8.2	2.94	2.80	2.05	1.15
50			10.72	60	7.87	28.4	5.11	9.9	3.27	3.32	2.27	1.38
70			15.01	113	11.02	53.0	7.15	18.4	4.58	6.2	3.18	2.57
90					14.17	84.0	9.19	29.4	5.88	9.8	4.09	4.04
100					15.74	102.0	10.21	35.8	6.54	12.0	4.54	4.96
120					18.89	143.0	12.25	50.0	7.84	16.8	5.45	7.0
140					22.04	190.0	14.30	67.0	9.15	22.3	6.35	9.2
160							16.34	86.0	10.46	29.0	7.26	11.8
180							18.38	107.0	11.76	35.7	8.17	14.8
200							20.42	129.0	13.07	43.1	9.08	17.8
220							22.47	154.0	14.38	52.0	9.99	21.3
240							24.51	182.0	15.69	61.0	10.89	25.1
260							26.55	211.0	16.99	70.0	11.80	29.1
280									18.30	81.0	12.71	33.4
300									19.61	92.0	13.62	38.0

U. S. Gal's per Min.	4" Pipe		5" Pipe		6" Pipe		8" Pipe		10" Pipe		12" Pipe		14" Pipe		15" Pipe		16" Pipe		20" Pipe		24" Pipe	
	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.	Vel.	Fric.
40	1.02	0.22																				
45	1.17	0.28																				
50	1.28	0.34																				
70	1.79	0.63	1.14	0.21																		
75	1.92	0.73	1.22	0.24																		
100	2.55	1.22	1.63	0.41	1.14	0.14																
120	3.06	1.71	1.96	0.58	1.42	0.25																
125	3.19	1.86	2.04	0.64	1.48	0.28																
150	3.84	2.55	2.45	0.88	1.71	0.32																
175	4.45	3.44	2.86	1.18	2.00	0.48																
200	5.11	4.40	3.27	1.48	2.28	0.62																
225	5.77	5.45	3.67	1.86	2.57	0.74																
250	6.40	6.72	4.08	2.24	2.80	0.92	1.60	0.22														
270	6.90	7.70	4.42	2.60	3.03	1.13	1.70	0.25														
275	7.03	7.99	4.50	2.72	3.06	1.15	1.73	0.27														
300	7.66	9.30	4.90	3.14	3.40	1.29	1.90	0.32														
350	8.90	12.32	5.72	4.19	3.98	1.75	2.20	0.42														
400	10.21	16.00	6.54	5.40	4.54	2.21	2.60	0.54														
450	11.50	19.80	7.35	6.70	5.12	2.65	2.92	0.68	1.80	0.21												
470	12.10	22.40	7.70	7.22	5.49	2.90	3.07	0.75	1.92	0.24												
475	12.20	22.96	7.76	7.42	5.55	2.95	3.10	0.76	1.94	0.25												
500	12.77	24.00	8.17	8.12	5.60	3.30	3.20	0.82	2.04	0.28	1.42	0.11										
550			8.99	9.60	6.16	3.93	3.52	0.97	2.25	0.33	1.57	0.14										
600			9.80	11.30	6.72	4.70	3.84	1.14	2.46	0.39	1.71	0.15										
650			10.62	13.20	7.28	5.40	4.16	1.34	2.66	0.46	1.85	0.19	1.37	0.09								
700			11.44	15.10	7.84	6.20	4.46	1.54	2.86	0.52	2.00	0.22	1.47	0.10								
750			12.26	17.20	8.50	7.00	4.80	1.74	3.00	0.59	2.13	0.24	1.58	0.11								
800					9.08	8.00	5.12	1.97	3.28	0.67	2.27	0.27	1.68	0.13								
850					9.58	8.95	5.48	2.28	3.48	0.75	2.41	0.31	1.79	0.14								
900					10.30	10.11	5.75	2.46	3.68	0.83	2.56	0.34	1.89	0.16								
950					10.72	10.80	6.06	2.87	3.88	0.91	2.70	0.38	2.00	0.18	1.73	0.12						
1000					11.32	12.04	6.40	3.02	4.08	1.01	2.84	0.41	2.10	0.19	1.82	0.14						
1050					11.90	13.30	6.70	3.21	4.29	1.09	2.98	0.44	2.20	0.22	1.91	0.16						
1100					12.50	14.31	7.03	3.51	4.50	1.20	3.13	0.49	2.31	0.23	2.00	0.17						
1150					12.95	15.60	7.35	3.84	4.71	1.34	3.27	0.53	2.42	0.25	2.09	0.18						
1200					13.52	16.69	7.67	4.15	4.91	1.46	3.41	0.57	2.52	0.26	2.18	0.19						
1250					14.10	18.50	8.00	4.45	5.11	1.51	3.55	0.62	2.63	0.29	2.28	0.20	1.99	0.18				
1500							9.60	6.27	6.10	2.09	4.20	0.85	3.15	0.39	2.73	0.28	2.39	0.31				
2000							12.70	10.71	8.10	3.65	5.60	1.43	4.20	0.68	3.64	0.54	3.19	0.39			1.42	0.05
2500									10.10	5.33	7.00	2.28	5.25	1.03	4.55	0.72	3.99	0.58			1.77	0.07
3000									12.10	7.80	8.40	3.15	6.30	1.47	5.46	1.12	4.79	0.80	3.08	0.27	2.13	0.10
3500									14.10	10.08	9.80	4.10	7.35	1.81	6.37	1.43	5.59	1.04	3.59	0.35	2.49	0.14
4000											11.35	5.32	8.40	2.47	7.28	1.85	6.38	1.34	4.10	0.45	2.85	0.18
4200											11.93	6.00	8.82	2.80	7.64	2.08	6.72	1.45	4.32	0.50		
45x0											12.78	6.90	9.45	3.22	8.19	2.23	7.20	1.65	4.62	0.56	3.30	0.22
5000											14.20	8.40	10.50	3.92	9.10	2.78	7.96	2.02	5.13	0.68	3.54	0.27
5500													11.55	4.65	10 01	3.36	8.78	2.39	5.64	0.82	3.90	0.33
6000													12.60	5.50	10.92	3.90	9.56	2.80	6.15	0.96	4.25	0.38
6500													13.65	6.45	11.83	4.55	10.36	3.32	6.66	1.06	4.61	0.49
7000													14.70	7.15	12.74	5.08	11.12	3.68	7.18	1.28	4.97	0.53
7200															13.10	5.45	11.50	3.96	7.38	1.35		
7500															13.65	5.90	11.95	4.28	7.66	1.45	5.32	0.59
8000																			8.17	1.65	5.68	0.66
8500																			8.68	1.83	6.02	0.74
9000																			9.20	2.04	6.35	0.81
9500																			9.70	2.25	6.74	0.91
10000																			10.40	2.53	7.07	0.98

Vel.—Velocity ft. per second. Fric.—Friction head in feet.

Here's how TRANSITE PRESSURE PIPE meets these 7 basic water-line problems...

IF YOU are faced with some—or all—of these 7 common water-line problems, here is information about Johns-Manville Transite* Pressure Pipe that may be of help to you...facts that tell how this modern asbestos-cement pipe is helping to solve these problems in many communities.

1. Handling costs:

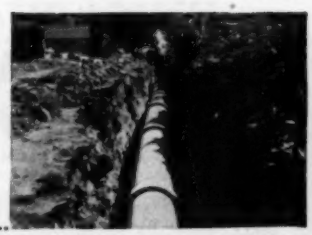
Because it is light in weight and easy to handle, Transite Pressure Pipe keeps handling costs down. Loading, unloading, and all other subsequent handling operations are simplified. More footage can be hauled per truckload—reducing trucking costs—and distribution along the trench is easier and more quickly accomplished. Moreover, mechanical handling equipment is not necessary except where larger sizes are being used; the pipe sections are easily lowered into the trench with rope slings.

2. Installation costs:

Transite Pressure Pipe offers important economies that help combat increasing costs of water-line installation. It is quickly and easily assembled in the trench. A coupling puller is the only tool necessary. Often, the pipe can be assembled so rapidly that the same foreman supervises both excavation and installation. The speed with which Transite is assembled means that the job is completed with a minimum of time and labor, thereby contributing important reductions in the overall cost of the system.

*Transite is a Johns-Manville registered trade mark

3. Soil corrosion:



Two factors give Transite Pressure Pipe exceptional resistance to corrosion: (1) the corrosion-resistant materials of which it is made; (2) the especially developed Johns-Manville process of manufacture which imparts a high degree of chemical stability to the finished pipe. This high resistance to corrosion has been substantiated by numerous installations. Many of these are serving as replacements in soils so destructive that the useful life of the pipe materials previously used had been seriously curtailed.

4. Internal corrosion:

Transite Pipe, because of its asbestos-cement composition, is not affected by tuberculation. Therefore, it is not necessary to resort to pipe of larger diameter to offset the internal effects of this costly form of pipe corrosion. And because progressive reduction of delivery due to tuberculation capacity is never a problem in a Transite pipe line, pressures and flows remain high—pumps operate at higher efficiencies. These factors are often reflected in better service and lower water rates in communities served by Transite lines.

5. Joint leakage:

Transite's Simplex Coupling was designed to minimize underground leakage . . . and to provide maximum protection against failures resulting from trouble at joints. It consists of only three parts: a Transite sleeve, machined to fit over the pipe ends, and two rubber rings which, when assembled, are tightly compressed between pipe and sleeve. The joint thus formed is tight and flexible. It remains tight in service. Furthermore, each joint may be checked for proper assembly immediately upon completion.

6. Vibration and stresses:

Transite's flexible joints effectively absorb the vibration of heavy traffic—an especially important factor where pipe is laid under busy highways, or near railroad and street car tracks. Because each joint is capable of deflection up to five degrees, the entire line has a flexibility not ordinarily found in other types of waterline construction. This helps compensate for soil movements and other stresses to which the pipe may be subjected . . . provides an effective safeguard against costly pipe failures.

7. Maintenance:

In thousands of communities, Transite Pipe—with its advantages of joints that remain tight and flexible, its corrosion resistance, and immunity to tuberculation—provides low-cost water transportation that requires little, if any, maintenance. Transite lines do not have to be cleaned, lined, or replaced because tuberculation has reduced their original capacity. Reports from communities all over the country prove that Transite's asbestos-cement structure provides economies that continue through the years.

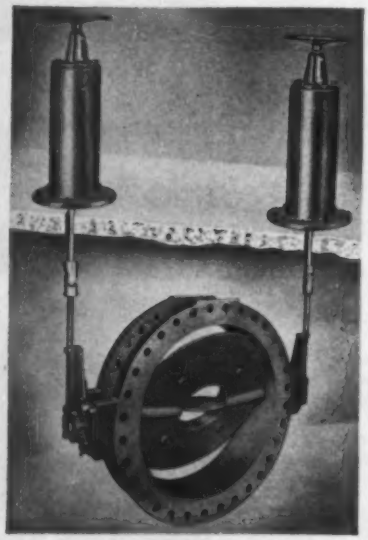
Transite Pressure Pipe is furnished in sizes from 4" to 36" inclusive, in three pressure classes. These classes are designated as 100, 150 and 200 which indicates maximum recommended working pressures of 100, 150 and 200 psi, respectively. For further information, write to Johns-Manville, Box 290, New York 16, N. Y. Ask for Brochure TR-11A.

JOHNS-MANVILLE JM PRODUCTS

Johns-Manville Transite Pressure Pipe

R-S valvEvents

• EXCERPTS FROM THE R-S BOOK OF EXPERIENCE •



No. 727

36 inch x 8 inch heavy duty dual valve with 125-pound Am. Std. flanges controls maximum flow with a small pressure drop in large 36-inch valve. By closing large valve, small inner 8-inch valve controls small flow with high pressure drop. Separate handwheel controls for each valve vane patented. Automatic control and drip tight rubber seat available.

7 Advantages of R-S VALVES

1. Economy in first cost. Minimum number of working parts.
2. Body assemblies correctly engineered mechanically and metallurgically. Equal or exceed A.S.A. standards in every detail.
3. Only a few handwheel turns required for opening or closing.
4. Less inherent pressure loss reduces pumping costs.
5. More control rangeability. Readily adapted to automatic operation.
6. Self-cleaning—no pockets to capture sediment—no objectionable turbulence or wire drawing.
7. Rotary motion of shaft reduces stuffing box problems.

R-S PRODUCTS CORPORATION
Wayne Junction • Philadelphia 44, Pa.

No. 680—Standard heavy duty valve with handwheel control—self-locking worm and gear. Automatic control and rubber seat available with 125-pound flanges. Rubber seated valves are drip tight with water at 100 psig and air bubble tight at 80 psig under temperatures up to plus 275° F. and as low as minus 40° F.

No. 771—Heavy duty wafer type valve equipped with handwheel control—self-locking worm and gear. One-piece body casting. Vane, shaft assembly and handwheel control identical with double flanged valve. Face-to-face dimension does not reduce torque. Flareout on body casting accommodates large mounting bracket base same as No. 680.

No. 734—72 inch 125 pound "H" metal valve for 800° F. Equipped with cooling fins, oil cylinder and positioner utilizing 200 psig operating oil pressure and 0-15 psig instrument air. Positioner cam driven simulating straight-line semi-log control curve or other characteristics if desired.

R-S field representatives maintain experienced engineering and maintenance staffs to study your valve problems, make recommendations and an appraisal of what you may expect from such studies. Specially trained factory representatives are also available for consultation.
Consult with your local R-S representative. Look for the address and phone number listed under "R-S Products, Valves" or write direct.

CAUSES AND PREVENTION OF WATER LOSSES*

HOMER E. BECKWITH
District Manager
The Pitometer Co., Pittsburgh, Pa.

IN the water industry the term "waste" covers a multitude of sins and it might be well to pause a while to examine the nature of some of these detours from rectitude. No plant, of course, sells 100 per cent of the water it produces. There are unavoidable sources of waste, which produce in every plant a certain irreducible loss.

Water losses may be due to one of more of a number of causes. "House waste" is a commonly encountered problem. Although the losses from individual leaks in this category may be slight, the total amount of water involved can be very great, because of the large number of such leaks. Losses resulting from underground leakage vary from very small quantities to several hundred thousand gallons a day—even exceeding 1 mgd. on rare occasions—for a single leak. The "slow" meter is another source of water loss, which may range from a few gallons a day on a defective house meter to several hundred thousand on a large industrial meter. A fourth cause of water loss is the unauthorized connection, and again the total may vary widely. This problem is not met with very frequently, but, when it does exist, the losses are often staggering. Defective master meters, underread industrial meters and readings spaced so far apart that the meters have turned over between checks are also responsible for registration losses.

Need for Meter Inspection

All accounted-for figures depend upon the accuracy of the master meter. This instrument is usually of the Venturi or orifice type and is kept in an excellent state of repair, registering accurately year after year. But occasionally something happens. It may be the recording apparatus, which can be easily checked and adjusted, but sometimes foreign matter gets into the throat of the Venturi tube or something else happens to disturb the ratio of the areas at the points where pressures are taken. In the older Venturi type, it was usually not easy to inspect this part of the meter, and without inspection no apparatus can be expected to continue to function properly year after year. Pitometer checks had shown a certain meter to be working perfectly as much as thirty years after installation. That is good service. Shortly thereafter further tests indicated that the meter had begun to overregister, a condition which gradually grew worse over the next few years, finally reaching 30 per cent. An inspection revealed that a large stone had worked its way into the tube and upset the pressure ratios, thereby causing the meter to overregister. In a very small number of meters, the pressure ratios have been affected by tuberculation and false registration has resulted, which is hardly surprising after thirty or forty years of faithful service.

Any piece of scientific equipment is entitled to a reasonable amount of care. Modern Venturi tubes are equipped with handholes to make inspection of the internal condition of the tube easy. Experience has shown that all types of master meters—Venturi, orifice plate, pilot tube or current wheel—perform excellently when properly chosen and properly maintained. But occasional independent accuracy checks by means of some instrument such as the pitometer are of great value in insuring that the figures being used for total water production are accurate.

Domestic Waste

Once assured that the production figures are correct, it should next be determined how much of the water delivered to customers is being profitably used or paid for. Originally all water was sold to domestic customers on a "flat-rate" basis. Some effort was occasionally made to control the amount of water used per service by limiting the diameter of the service pipe, sometimes to ½ in. or even less. These attempts proved ineffectual, however, except in holding down the peak demand rate, since they did little to eliminate the small but persistent leaks which continued throughout the day but which were not of sufficient size seriously to affect the pressures or the supply of water for normal use.

There are two methods in general use for controlling domestic water waste. One is the examination of house fixtures by qualified inspectors, either on an overall or a selective basis, with penalties invoked for failure to keep plumbing in a good state of repair. The other method is the installation of meters on domestic services, again either completely or selectively. Which means should be chosen is a matter of economics, depending on the amount of the existing waste and its cost. Some small cities, where there are no sewer systems and where persistent fixture waste will quickly cause cesspools or septic tanks to overflow, may have a per capita consumption of as low as 40 gpd. Unless this water has a high production cost, it may be uneconomical to spend much money to reduce the loss. In other cities, where facilities exist for draining off the waste without inconvenience to the wasteful consumer, the per capita use and waste of water may reach 300 or even 400 gpd. Even with low-cost water, some effort to control wastage is clearly indicated when consumption is anywhere near this high. Inspection and forced repair of defective plumbing fixtures may serve the purpose, but more and more cities are resorting to the metering of domestic services. In order for this method to be effective, the meters must be kept in repair and read at proper intervals.

Registration Losses

The author has always felt that sensitivity is a trait more to be desired in a domestic meter than extreme accuracy. The meter is a mechanical device and it takes energy to move it. The energy necessary for sufficient water to slip around the working parts of the meter and cause a small but steady drip is so little that few if any of the meters in current use will register it. How large an amount can slide through without causing the meter to turn depends on its sensitivity—its inertia or resistance to movement. And the sensitivity of the meter determines the size a fixture leak must attain before it begins to cost the customer money. It must not be forgotten that small drips will usually not register on even the newest and best of the meters in popular use. Such leaks therefore become one of the items in the total of unaccounted-for water. Furthermore, a little reflection will show that the amount lost depends upon the number of meters and not upon how much water flows through the meters. As the average use through each meter increases, the percentage of loss from drip decreases. Meters which may be 100 per cent accurate at a relatively high rate of flow but which do not start to register until an appreciable flow occurs are a fertile source of loss. On the other hand, a meter which causes an increase in the water bill whenever a relatively small fixture leak is permitted to persist makes the customer "waste minded" and cuts down the amount of wasted water.

Loss in registration can also result from too infrequent reading of the meters. The author recalls one city where the careful investigation of a night flow rate of approximately 30,000 gpd. in a single block failed to disclose any indications of underground leakage. Inspection revealed that several meters were turning at a constant rate of ¼ cfm. or more—over 360 cu.ft. a day or 130,000 cu.ft. a year. As the meters were only read once a year, and as the capacity of the reading dial was only 100,000 cu.ft., the meters turned completely over between readings and the customers were billed for only part of the water actually used. There were indications that some of the meters had turned over at least twice between readings. The remedy here manifestly is more frequent readings or an increase in the capacity of the reading dial. Some smaller industrial meters turn over between readings which are six months apart.

Several years ago a survey in a certain small city brought to light the fact that the high loss was almost entirely the result of underreading the large industrial meters. The smallest reading unit on the large meters was ten times the size of the smallest unit on the domestic meters and was so marked. The meter reader, however, paid no attention to the markings and year after year read the meters at 10 per cent of the actual consumption.

In passing, it might be mentioned that cubic-foot meters occasionally get mixed into a system where all the rest are gallon meters, or vice versa, and incorrect readings result.

Another source of lost water, or at least lost registration, is the industrial meter which does not accurately record the flow through it, because the meter is worn out or otherwise defective, or because it is improperly set or unwisely selected. Manufacturers make several types of meters, each of which is especially designed to do a certain kind of work. Some perform best under high continuous flows, some under relatively low flows and some under a combination of both. Moreover, the manufacturer's instructions about setting the meter must be followed or incorrect registration may result. Satisfactory service can be assured only if meters are correctly chosen as to type and size and are properly set.

Meters are mechanical instruments and even the best machines eventually wear out. Although registration may continue, worn gears and other frailties of old age gradually decrease meter accuracy. Meters are the cash registers of the water works system and justify every bit of attention and care required to keep them in proper working condition.

*Reprinted from JAWWA, Vol. 41, p. 222, by permission.

Occasionally it would be found that industrial customers are taking water through unauthorized connections or unmetered fire lines—often in spectacular amounts. The author knows of one plant which took nearly 2 mgd. and had apparently been doing so for 25 years. It is remarkable, however, that in most such instances the top management of the offending company has no knowledge of what is taking place. Some minor official is usually just trying to make a showing. Most people are honest.

Underground Leakage

The source of greatest losses is the hidden, underground leak, which may vary in size from a few gallons a day to over a million. Underground leaks occurring on mains are usually due to blown joints, broken or split mains, holes, rotted wooden plugs and the like. Those on services are due principally to broken corporation cocks, defective wiped joints, blown gaskets, split pipe, or pipe disintegrated by corrosion or electrolysis. The escaping water gets into sewers, gravel beds, culverts, streams, limestone caves and so forth. Even after more than 25 years' experience in detecting and locating leaks, the author is frequently surprised by some new combination of circumstances which will permit water to escape from such a leak without any surface indication of its existence. The increase in the amount of paved streets has been a factor in keeping many leaks hidden.

As previously stated, some leaks are too small to be detected by any presently known method, and, even if they were definitely located, the cost of repairs would be excessive. These small leaks are an important factor in irreducible losses. Here again, the amount of loss depends on the size and number of the mains and not on the quantity of water they carry. If the water use from a particular pipe were doubled, the increase would not cause a single gallon more to be lost from that pipe. In other words, the percentage ratio of the seepage to the use would be cut in half.

Other factors, such as leakage and evaporation from reservoirs, also contribute to the irreducible loss.

Water Waste Surveys

The three principal causes of irreducible losses are fixture drips too small to register on meters, small seeps from mains, and evaporation and other reservoir losses. None of these three bears any direct relation to the amount of water put into the system. For this reason, it is impossible to give any overall figure for reasonable losses. Some plants should, and do, account for approximately 90 per cent of the water produced. Others, with a very low per capita use or an excessive main mileage in relation to the amount of consumption, can under the best of conditions account for only a much smaller percentage. It requires a water waste survey, planned in such a way that it will detect and locate all of the preventable sources of waste, to determine what the unavoidable loss is on any particular system.

The pitometer water waste survey is intended to be that type of survey. It is based upon a series of direct and indirect measurements with the pitometer which determine the amount of water entering the system and its distribution throughout the system. A properly designed pitometer survey has several functions:

1. It checks the master meters for accuracy by independent comparative flow measurement.

2. It divides the distribution system into districts containing a few miles of main each and obtains a 24-hour measurement of the total flow into each district, together with the variation in that flow.

3. It tests large industrial meters for accuracy by independent comparative flow measurement.

4. It checks large industrial plants for unauthorized connections, again by flow measurement.

5. It determines the distribution of the night rate of flow almost block by block, so that the location, as well as the amount of the waste, can be determined. Through further investigations conducted by suitable methods wherever these measurements show abnormal flows, all leaks are definitely located for repair and all other sources of waste are disclosed.

That is to say, the survey tells where the water goes and why it goes there. It eliminates guesswork and clearly shows the exact nature of the waste, so that remedial steps may be taken. Underground leaks are located and can be dug up and repaired. If residential waste is involved, the responsible areas, or even individual properties, are discovered, making possible the elimination of the waste by inspection and repairs or by metering. Defective industrial meters or unauthorized industrial use is detected, and the meters can be repaired or replaced. If it is found that meters are not being read often enough, the period between readings can be shortened. Once the disease has been correctly diagnosed, the remedy is clearly indicated.

When such a survey has been made and all the waste stopped, then and only then can the percentage of "unavoidable" waste for a particular plant be determined.

A question frequently asked is what size of community can profitably make a water waste survey. The answer is that there seems to be no maximum or minimum limit. Some of the most outstandingly successful surveys have been made in communities of more than a million population, while others have been equally successful in communities of less than a thousand population. A single leak wasting 50,000 gpd. would be a very small item in a system using 100 mgd., but in a small community with a total daily consumption of 100,000 gal. it would amount to half of the output. Although most of the really large individual leaks have been found on the larger systems, the surveys which have resulted in the highest percentage of water loss reduction have usually been made on smaller plants. The operation of the survey is flexible, and methods are readily adaptable to the various field conditions encountered—including the size of the community.

The amount of "preventable" waste which should be permitted to exist before a determined effort is made to locate and eliminate it depends on the value of the water—its cost of production, the quantity available and other widely varying factors. The least valuable water is probably that taken from a gravity supply having surplus storage and transmission capacity, although as the demand approaches the capacity of the plant this water can become extremely precious. Most expensive is the water obtained from limited supplies with high purification and softening costs. Each system has to be studied upon the basis of local conditions, but there will always be a point at which waste becomes too costly to be tolerated. When that point has been reached or passed, a careful, scientifically planned survey such as the one previously outlined will best serve to bring the losses down to a minimum.

BLOTTING OUT WASTE

Safe Water
delivered night and day
Costs Less
than anything else you buy
· · but · ·
Don't Ignore Leaks!

Satisfied customers are worth more to us than revenue secured from water uselessly passing through meters.

INDIANAPOLIS WATER CO.

What Leaks May Cost

Size of Leak		Gallons per 24 Hours	Gallons per Month	Cost per Month
½"	◯	47,600	1,451,800	$136.21
¼"	○	12,300	375,150	60.05
⅛"	o	3,200	97,600	19.65
1/16"	∘	860	26,230	6.35
1/32"	·	215	6,550	1.97

[Above estimates are based on [illegible] pressure without allowance for friction loss]

The above is a reproduction of the top side of a little blotter sent out to customers, reminding them of the high cost of allowing fixture leaks to persist. If as good at blotting waste as ink, the scheme is praiseworthy.

Incidentally, the Indianapolis Water Company gets in a good public-relations message about satisfied customers being worth more to them than the added revenue from the uselessly metered wastage.

VALVE AND PRIMER CORPORATION

30 WEST WASHINGTON ST., CHICAGO 2, ILL.

Apco Automatic Pump Primers *Apco Automatic Air Relief Valves*
V-Apco Automatic Vacuum Primers

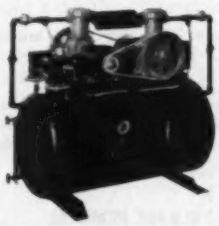
V-APCO Automatic Vacuum Primers and APCO Automatic Pump Primers

Advantages

V-APCO Automatic Vacuum Primers for centrifugal pumps offer these advantages: 1) Keep pumps always primed. 2) End loss of time due to lack of prime. 3) Operate at any vacuum under which the centrifugal pump will operate. 4) Uses no foot valve. 5) Flexible capacity; will serve additional pump installations satisfactorily. 6) Does not affect pump efficiency. 7) Improves operation of pump. 8) Simple design insures long life, freedom from trouble, highest efficiency.

How the Primer Operates

Drawing below shows the V-APCO Primer. A priming valve of the 200 series is placed on the vent of the centrifugal pump. While the vacuum pump is producing a vacuum, the valve passes all air that



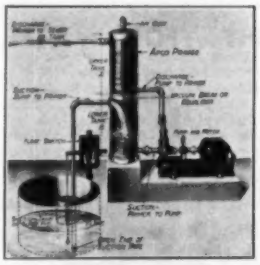
may be in the pump or suction line. When the air is withdrawn, it is followed by water which raises the valve float. That closes the outlet and prevents flooding of the vacuum pumps.

The Air Release Valve is mounted on the pump and connected to the vacuum storage tank that stores enough vacuum to act as a cushion on the vacuum pump. It provides a way to withdraw small amounts of air from the pump and suction lines from time to time. This makes frequent starting and stopping of the vacuum pump unnecessary.

A vacuum breaker on the vacuum tank unloads the vacuum pump in the unlikely event that is required. A vacuum switch with vacuum release connections is mounted on the vacuum tank and starts the vacuum pump when the vacuum drops in the storage tank and stops the pump when full vacuum has been reached. The vacuum release connection unloads the vacuum pump when it is not operating and places it in condition to start at no load.

The check valve between the switch and the pump is a special noiseless one for the purpose, holding the vacuum in the storage tank when the pump is not operating.

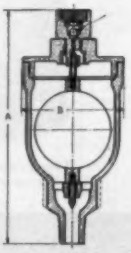
THE APCO PRIMER



How the Apco Primer Works

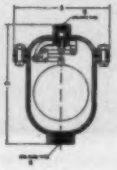
This cut shows primer in service with the pump running. When the pump starts, it draws liquid from the lower chamber of the primer and discharges it through the upper chamber. The withdrawal of the liquid from the lower chamber creates a partial vacuum in this chamber which causes the liquid in the sump or well to rise in the suction pipe and flow through the primer to the pump. When the pump stops, the liquid in the upper chamber runs back through the pump into the lower chamber by gravity, thus refilling the lower chamber with liquid to prime the pump when it starts again.

Sectional View of Valves No. 50-60 for Pressures Up to 60 Lbs.



Sectional View of Valve No. 30 H.D. for Pressures up to 150 Lbs.

Sectional view of Valve No. 200. The valve has large venting capacities and positive opening when under vacuum.



Sectional view of Valve No. 200-A.

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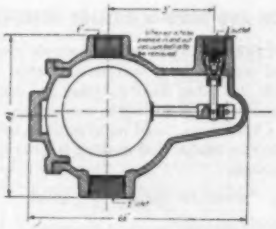
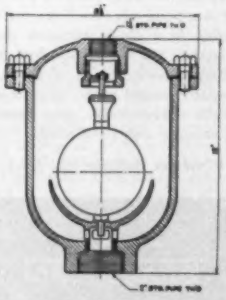
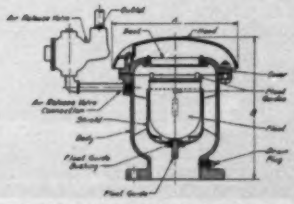


Sectional View of Valve No. 55.



Sectional View of Valve No. 140 for Deep Well Pumps.



Sectional View of No. 150 Series Air and Vacuum Valves.

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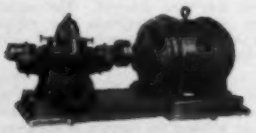
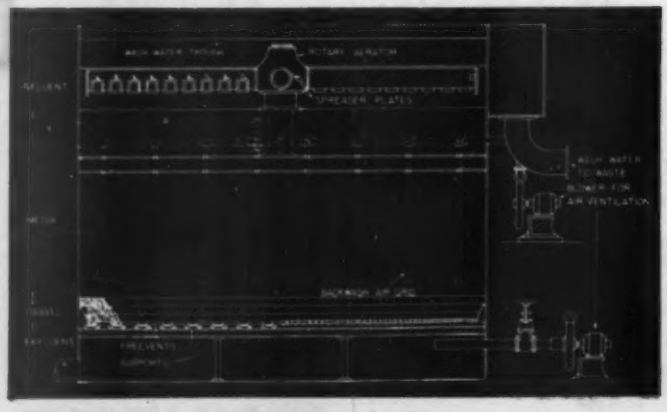


Horizontal Double Suction



Sectional View of Ferrofilter

Measuring Pump Performance During Operation*

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PUMPING costs are one of the major operating expenses of water supply systems. Hence, it pays to keep close check on the performance of the pumps to be sure that they are operating at peak efficiency and that the pump and motor have been selected correctly in the first place. After having inspected pumps for twenty years, the author is still surprised to find a considerable number which were not properly chosen and which are greatly overmotored.

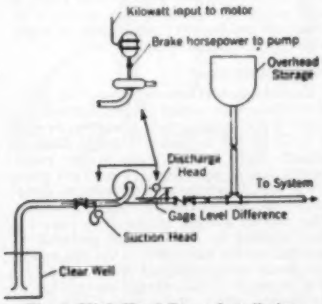


Fig. 1. High-Head Pump Installation

The object of this paper is to present methods of measuring pump performance while in operation so that pumps which are poorly selected or which are not performing as they should can be readily detected. The mehods given are for field checking purposes and cannot therefore be expected to have the high accuracy attained in the laboratory.

*Reprinted from JAWWA, Vol. 41, p. 227 by permission.

Four quantities must be measured in order to check pump performance properly: the total head, the input horsepower, the quantity of water pumped and the rotation speed. These measurements must be taken simultaneously under the same conditions while the flow, head and speed are steady. Other flow rates are then taken if the whole performance curve of the pump is desired.

Pump Heads

A typical high-head pump arrangement for a water plant is shown in Fig. 1. The total head (H_t, in feet) developed by the pump for this arrangement is given by Eq. 1 and represents the actual amount of useful energy that the pump imparts to each pound of water:

$$H_t = H_D - H_s + H_{GD} + H_{V.D} - H_{V.S} \qquad (1)$$

In this equation, H_D is the discharge gage pressure, in feet, equaling 2.31 times the gage pressure in pounds per square inch; H_s is the suction gage reading, in feet, equaling 1.13 times the gage reading in inches of mercury; H_{GD} is the gage level difference, in feet, equaling the discharge gage center elevation minus the elevation of the suction gage *connection;* $H_{V.D}$ is the velocity head in the discharge pipe, in feet; and $H_{V.S}$ is the velocity head in the suction pipe, in feet, equaling the square of the velocity, in feet per second, divided by 64.34.

The gages used should be calibrated with a dead-weight tester and care should be taken not to use pipe connections larger than ¼ in. for the gages. The gage pipe connections should not extend beyond the pipe wall but should be flush and free of all burrs on the inside.

The velocity head, which is the energy the pump has to put into the water to bring it up to the speed in the pipe, may be taken from Fig. 2. For example, the velocity head for 1,400 gpm. flowing in a 10-in. pipe is 0.5 ft.

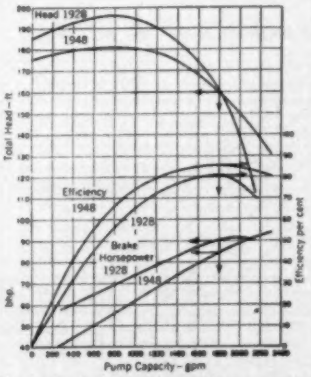


Fig. 3. Comparison of Pump Characteristics
Data from American-Marsh Pumps, Inc.

Horsepower and Efficiencies

The actual horsepower (whp.) imparted to the water as it flows through the pump will be:

$$\text{whp.} = \frac{H_t \times \text{gpm.}}{3{,}960} \qquad (2)$$

with H_t being the total head, in feet, and "gpm." the pumping rate in gallons per minute.

The input shaft horsepower or brake horsepower from the motor is greater than the water horsepower because of the various hydraulic and mechanical losses of the pump. The brake horsepower (bhp.) is given by:

$$\text{bhp.} = \frac{100 \text{ whp.}}{\text{pump efficiency (\%)}} \qquad (3)$$

The electrical power input to the motor is greater than the brake horsepower output

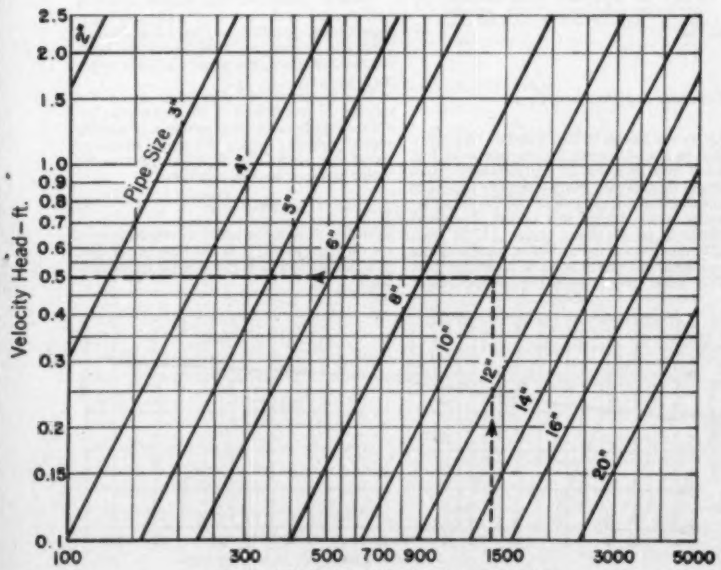


Fig. 2. Velocity Head for Various Flow Rates

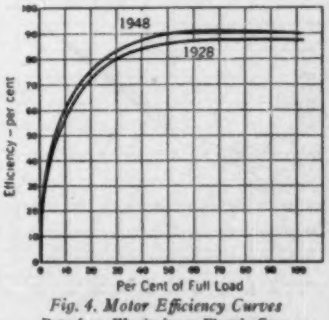
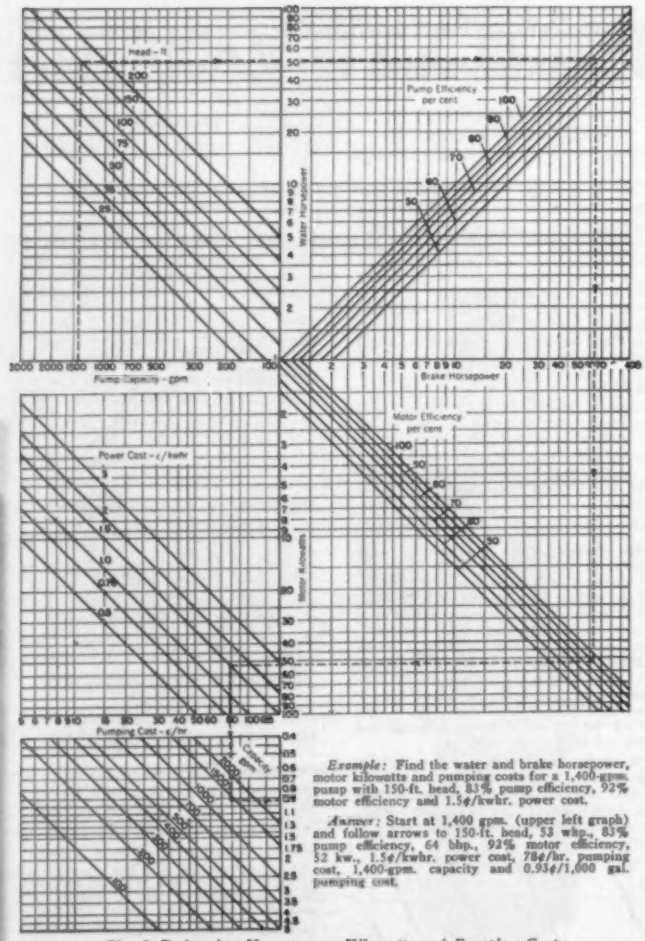


Fig. 4. Motor Efficiency Curves
Data from Westinghouse Electric Corp.



Example: Find the water and brake horsepower, motor kilowatts and pumping costs for a 1,400-gpm. pump with 150-ft. head, 83% pump efficiency, 92% motor efficiency and 1.5¢/kwhr. power cost.

Answer: Start at 1,400 gpm. (upper left graph) and follow arrows to 150-ft. head, 53 whp., 83% pump efficiency, 64 bhp., 92% motor efficiency, 52 kw., 1.5¢/kwhr. power cost, 78¢/hr. pumping cost, 1,400-gpm. capacity and 0.93¢/1,000 gal. pumping cost.

Fig. 5. Estimating Horsepower, Kilowatts and Pumping Costs

because of the electrical and mechanical losses within the motor. The kilowatt input, then, is given by:

$$\text{kw.} = \frac{74.6 \text{ bhp.}}{\text{Motor efficiency (\%)}} \qquad (4)$$

Typical pump and motor performance curves are shown in Fig. 3 and 4. The motor data in Fig. 4 are not for the pumps of Fig. 3 but may be taken as representative. Two sets of data twenty years apart are presented to bring out the magnitude of the improvements made during this period. The peak efficiency of the 6-in. pumps (1,750 rpm., 1,800-gpm. capacity at 160-ft. head) shown in Fig. 3 was raised from 81 to 86 per cent. The peak efficiency of the 30-hp., 220-v., three-phase, 1,750-rpm. induction motors shown was raised from 87.5 to 90.5 per cent. The combined efficiency, or wire-to-water efficiency as it is sometimes called, has increased from 71 to 78 per cent, which means that almost 10 per cent of the pumping cost may be saved, as compared with a 1928 installation, by changing to a modern pump and motor. This does not take into account twenty years of wear which makes modernization even more attractive. To put it another way, a 10 per cent saving for the pumps shown in Fig. 3, at a rating of 1,800 gpm. and a 160-ft. total head, means that $1,350 a year will be saved if the pump operates continuously and power costs 2c per kilowatt-hour.

A convenient chart for quick estimates of water horsepower, brake horsepower, kilowatts and pumping costs per hour and per 1,000 gal. is given in Fig. 5. This chart is also useful for checking the accuracy of computed results from pump tests to detect gross errors of calculation.

Power Measurement

One of the most convenient ways of measuring the power output of induction motors, without interrupting their operation, is with a hook-on volt-ammeter. Usually there is enough slack in the wires in the motor starter box to take readings for each phase —the method given here pertains to three-phase circuits but can be adapted to others. The average current of the three phases is then divided by the full-load amperes, as stamped on the nameplate of the motor, and the power output obtained from Fig. 7 (1). For example, if the average current for an 1,800-rpm., 220-v., 30-hp. motor with a full-load current of 75 amp. is 50 amp., 50/75 equals 67 per cent of the full-load current, and the power output is 62 per cent of 30 hp., or 18.6 hp. This example is shown by the dotted lines on Fig. 6.

The volt-ammeter is convenient for checking to see that the motor nameplate voltage is maintained, and it will also reveal any serious unbalance between the three phases. This method of power measurement should usually yield results accurate to within about 3 per cent.

Another method of determining power is with the aid of the watthour meter. A watthour meter installed on the pump control panel can be used, or, if the rest of the plant can be shut down, the plant watthour meter may be used.

The procedure is simply to count the number of revolutions of the meter disc for a timed interval (three minutes is usually enough) during which the water measurements are taken. The electrical input to the motor is given by the equation:

$$\text{kw.} = \frac{3.6RK}{S} \qquad (5)$$

in which R is the number of revolutions of the disc in time S; S is the time of the test, in seconds; and K is the overall meter constant.

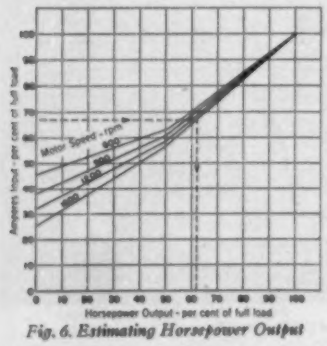


Fig. 6. Estimating Horsepower Output

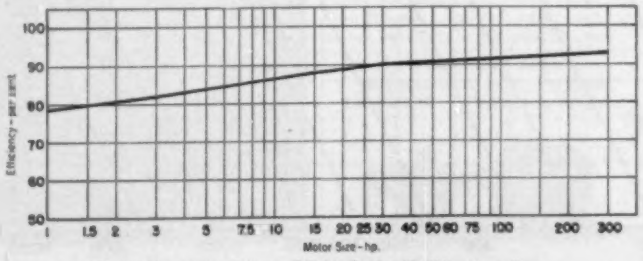


Fig. 7. Three-Phase Motor Efficiencies for Half Load or Above

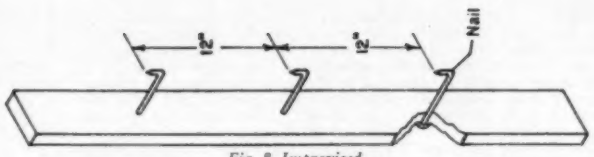


Fig. 8. Improvised Hook Gage

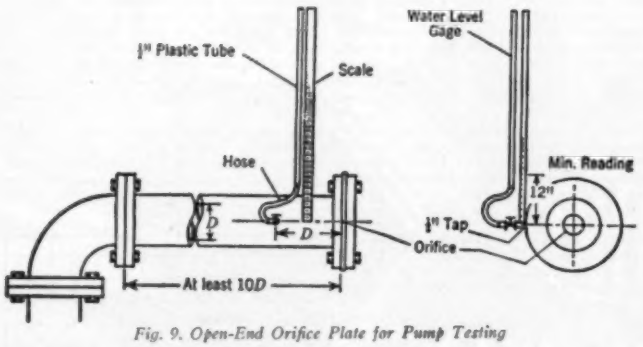


Fig. 9. Open-End Orifice Plate for Pump Testing

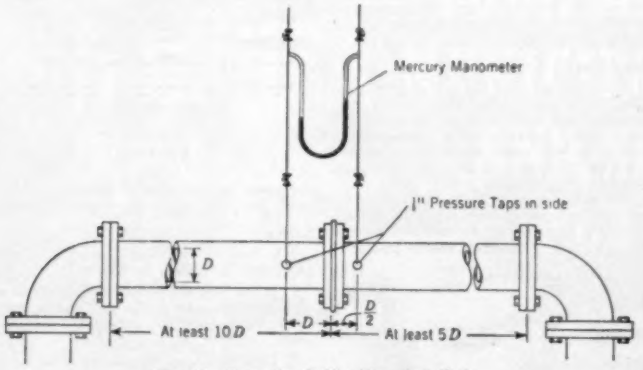


Fig. 10. Alternative Orifice Plate Installation

The meter constant is usually shown on the disc as $K = 0.6$ or on the meter nameplate as $K_h = 0.6$. A constant of 0.6 means that 0.6 whr. of electricity is used for each revolution of the disc. Of course, the constant may have other values. If potential and current transformers are used with watthour meters, as is frequently done, their stepdown ratios must be used to get the overall meter constant, K.

To illustrate, assuming that the meter constant is 0.6 with a 10:1 potential transformer and a 5:1 current transformer, the overall meter constant is (0.6) (10) (5) or 30 whr. per revolution.

The brake horsepower output of the motor is obtained from the equation:

$$\text{bhp.} = \frac{\text{kw.} \times \text{motor efficiency (\%)}}{74.6} \qquad (6)$$

Motor efficiencies for typical alternating current motors with half load or more are given in Fig. 7. The accuracy of this method should be about as good as that with the hook-on volt-ammeter method. For example, assuming that an overall meter constant of 0.6 applies to a 100-hp. motor being tested, it is desired to find its brake horsepower output if the meter makes 123 revolutions in three minutes. From Eq. 5, the kilowatts to the motor will be (3.6) (123) (30) ÷ (3) (60) = 73.8 kw. Since Fig. 8 shows a 91 per cent efficiency for a 100-hp. motor, the brake horsepower given by Eq. 6 is (73.8) (91) ÷ 74.6 = 90 bhp.

Water Measurement

Accurate measurement of pump capacity is usually more difficult to make in the plant than either head or power measurement. Sometimes a plant Venturi or orifice meter exists which can be valved to measure the flow from one pump at a time. If the meter has been checked for accuracy, the problem is easy, but more often other means have to be employed for field testing, such as measured tanks or filter basins, orifice plates, pitot tubes or weirs. Weirs will not be considered in this paper in order to keep it to a reasonable length.

If the pump discharge can be diverted into a filter or a tank which has been carefully measured, the capacity can be determined by timing the rate of level rise with an improvised hook gage and a stopwatch. This will give the cubic feet per minute flowing, and the gallons per minute can easily be secured. Sometimes the tank may be more conveniently located on the pump suction side rather than on the discharge side. A satis-

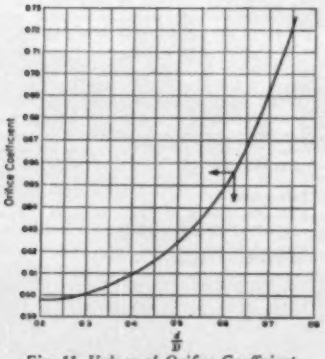


Fig. 11. Values of Orifice Coefficient

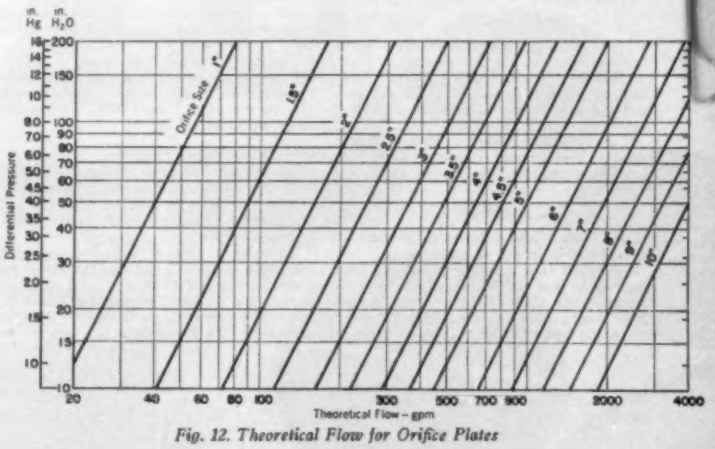


Fig. 12. Theoretical Flow for Orifice Plates

factory hook gage can be made by nailing through a 1 × 4-in. board and turning the ends of the nails up as shown in Fig. 8. The time for several successive nail points just to break through the water surface should be taken to secure check readings.

Frequently orifice plates offer a fairly simple method of field testing, particularly for well pumps. The orifice in the plate should be lathe-cut and not over 1/16-in. thick, and the upstream edge must be sharp and free of all burrs but not rounded. The plate is concentrically bolted to the end of a flanged pipe as shown in Fig. 9. Sometimes the plate can be slipped between the flanges of a straight run of pipe as in Fig. 10. Care must be used when putting in the ¼-in. pressure taps to see that they are smooth inside with no burrs and that they do not extend past the pipe wall.

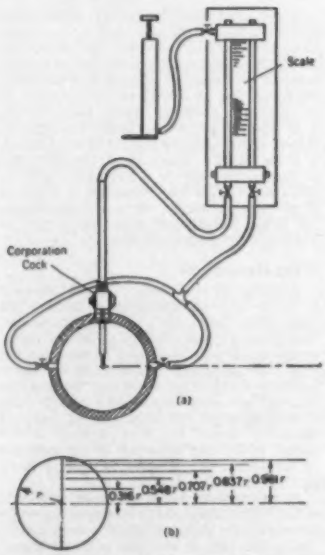


Fig. 13. Pitot Tube Installation

The flow (Q, in gallons per minute) indicated by an orifice plate is obtained from the formula:

$$Q = 5.68CD^2\sqrt{h_w} \qquad (7)$$

in which C is a coefficient dependent upon the ratio of the orifice diameter to the internal diameter of the pipe; d is the orifice diameter, in inches; and h_w is the differential pressure on the orifice, in inches of water.

If the arrangement of Fig. 10 is used with a mercury manometer completely filled with water over the mercury, a more convenient equation is:

$$Q = 20.2CD^2\sqrt{h_m} \qquad (8)$$

in which h_m is the differential pressure on the orifice, in inches of mercury.

Figure 12 is a graphical solution of the theoretical flow of the orifice exclusive of the coefficient C. Values from Fig. 12 have to be multiplied by C from Fig. 11 to get the actual flow. Figure 12 is also helpful in selecting the proper size of plates for a test.

The pitot tube, invented in 1730 by the French engineer Henri Pitot, is still one of the best devices for making field measurements of the capacity of pumps. The arrangement of the tube, as successfully used for many years by Gregory (2), is shown in Fig. 13(a) and the points in the pipe where the tube is placed are shown in Fig. 13(b). A tube which is a slight modification of Gregory's and which is built in accordance with the standards of the Hydraulic Institute can be inserted through a standard 1-in. corporation cock or a 1-in. gate valve. Ten diameters of straight pipe should be ahead of the tube position and five diameters should be after it.

Because the pitot tube measures the velocity of the water at a point, a traverse of the pipe must be made to determine the average velocity. Usually ten readings are sufficient for field work. The tube is placed at the points shown in Fig. 13(b) and each differential pressure is converted to velocity (V, feet per second) by:

$$V = 2.32\sqrt{h_w} \qquad (9)$$

in which h_w is the differential pressure, in inches of water. The flow is then secured from the internal pipe diameter (in inches) and the average of the ten velocities by the formula:

$$Q = 2.45D^2V_{avg.} \qquad (10)$$

If sufficient straight pipe is available to give a symmetrical flow pattern in the pipe, the average velocity is approximately equal to 0.84 times the velocity indicated at the center of the pipe.

Pump Speed

It is necessary to measure the rotation speed of a pump when checking its performance and to correct all readings to a single speed before plotting the results as in Fig. 3. The speed can be taken with a calibrated tachometer or a simple revolution counter and stopwatch.

The motor speed will vary slightly at the several load points during a test and the following formulas can be used to correct to one standard speed, S_s: Capacity at S_s:

$$gpm_s = gpm_m \frac{rpm_s}{rpm_m} \qquad (11a)$$

Head at S_s:

$$H_s = H_m \left(\frac{rpm_s}{rpm_m}\right)^2 \qquad (11b)$$

Horsepower at S_s:

$$bhp_s = bhp_m \left(\frac{rpm_s}{rpm_m}\right)^3 \qquad (11c)$$

The subscript s refers to the standard speed and the subscript m to the measured speed at each test point.

The coefficient C in both Eq. 7 and 8 depends upon the ratio of the plate hole diameter (d) to the actual inside diameter (D) of the pipe. Values of C for various ratios are given in Fig. 11.

Determining Proper Selection

All of the foregoing measurements are incidental to the main question of whether or not the pump is selected properly and whether it is operating properly in a given system.

Referring to Fig. 1 and assuming that 1,800 gpm. is needed, and that the lift of the water from a full clear well level to a low level in the overhead storage tank is 120 ft., the head required to pump various amounts of water to the system will be given by the minimum system head curve in Fig. 14. A high-lift condition would require a lift of 150 ft., and this maximum system head curve is also shown in Fig. 14. The two conditions given here are purposely exaggerated as compared with usual operating practice.

If the head-capacity curve for the 1948 pump is taken from Fig. 3 and put on Fig. 15, it will cross the two system curves at points A and B. It is important to note that once the pump is connected to the system it can operate only between these two limits and along its own head-capacity curve. In this example, the limits are from 1,610 to 2,030 gpm., and the pump should be specified for 1,800 gpm. at 160-ft. total head, as this would be close to its usual operating condition. Examination of Fig. 3 shows that the pump develops its maximum efficiency in this range.

A test will show whether or not the pump is properly selected for operating near its peak efficiency. Also, a curve similar to Fig. 3 will be furnished by the pump manufacturer for each pump, and the test results

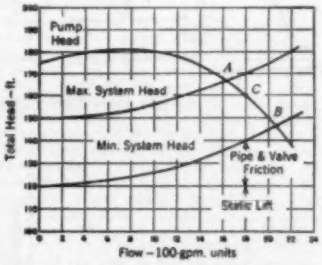


Fig. 14. Pump Selection for Maximum Efficiency

can easily be compared to determine if the pump performance is up to design value.

Summary

The data and methods presented in this paper may be briefly summarized:

1. It has been shown that the replacement of twenty-year-old pumps and motors may result in worthwhile savings in pumping costs.

2. Field methods of measuring pump head, horsepower, kilowatts in-put, capacity and speed have been presented.

3. Convenient graphical methods of estimating and checking pump performance have been given.

4. The determination of whether or not the pump is performing in accordance with its design characteristics can be made with the aid of the methods and data given.

5. A method for ascertaining whether or not a pump is properly selected has been given. It has been shown that a pump can operate only within the limits determined by the system head-capacity curves and that it is important for the balance point to correspond to the peak of the pump efficiency curve.

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1. Setter, Joseph A. Motor Horsepower From Ammeter Readings. Southern Power & Ind. (Jan. 1943).
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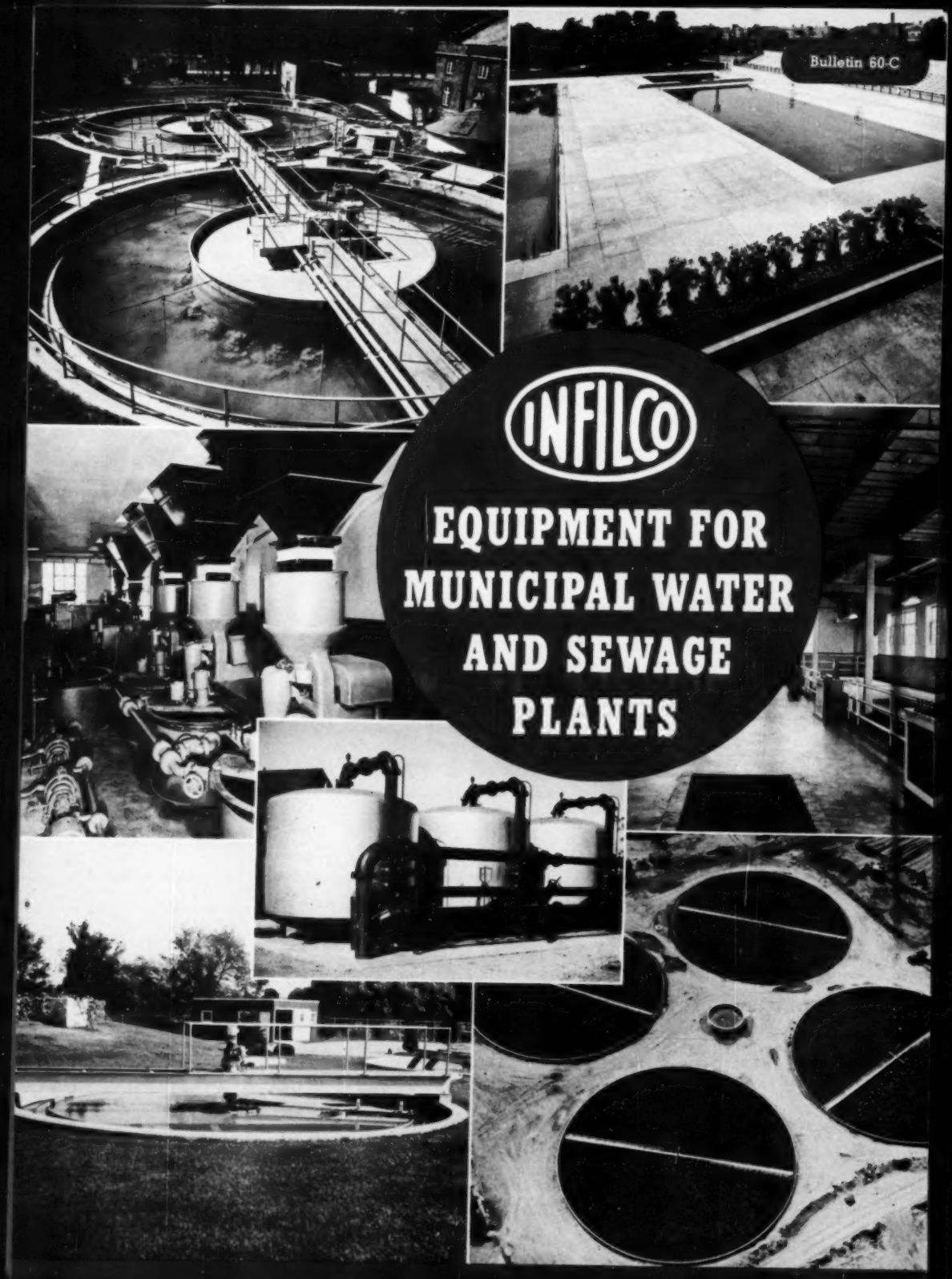

Bulletin 60-C
INFILCO
EQUIPMENT FOR MUNICIPAL WATER AND SEWAGE PLANTS

INFILCO WATER CONDITIONING EQUIPMENT

Infilco has for more than fifty years specialized in the design and manufacture of all types of equipment for municipal water conditioning plants—softening and filter plant equipment, recarbonators, chemical feeders and proportioners, gauges, hydraulic controls, etc. By providing a complete range of water conditioning equipment, Infilco offers the user the important advantage of undivided responsibility.

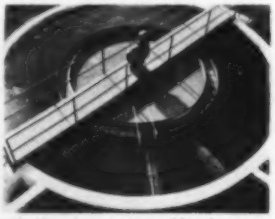
A complete laboratory and a staff of competent engineers are available for making recommendations and reports to the consulting engineer or his client. It is, of course, intended that this service shall cooperate with, and not conflict with, the work of the engineer.

WATER SOFTENERS

There are Infilco water softening plants for every requirement and for every type of water. You may depend upon our unbiased recommendation for your particular needs. Thousands of softening plants of various types in use the country over testify to the continued satisfactory service rendered by these units.

ACCELATORS® FOR SOFTENING, CLARIFYING AND STABILIZATION

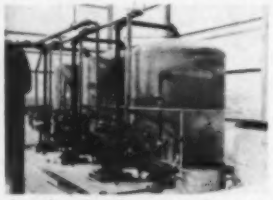
The Accelator for water softening, clarification, or stabilization is one of the most important water treatment developments in recent years. It is the most outstanding of the modern high-rate treating plants, as evidenced by the more than 1100 Accelators now in service. It replaces in a single basin the old style separate processes of mixing, coagulation and sedimentation. Not only does it save up to 80% in space, but it also produces a cleaner, more stable effluent than is available with any other type. This means greater chemical economy, longer filter runs, easier operation, and less maintenance. The principle of slurry recirculation and dynamic separation are unique with the Accelator.



ZEOLITES AND ZEOLITE SOFTENERS

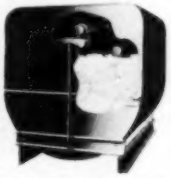
Infilco zeolite softeners are of either pressure or gravity type, and are built in sizes to meet any capacity requirement. Controls are furnished for either manual, semi-automatic, or fully automatic operation as desired.

A variety of Infilco zeolites is available, and the selection of type to be used will depend upon the characteristics of the water to be softened and upon requirements. All Infilco zeolites are capable of quick regeneration, considerable overload capacity and operation at high rates of flow.



CHEMICAL FEEDERS

Infilco dry chemical feeders provide means for accurate volumetric and gravimetric measurement of powdered, granular, or lump materials such as lime, alum, soda, carbon, etc. Capacities are from a fraction of a pound to hundreds of pounds per hour. Solution and wet chemical feeders are available in numerous types and many sizes to meet any requirement for accurately measuring and feeding chemical solutions and slurries.



LIME SLAKERS

The Infilco lime slaker combines in one continuous, automatic process the economical feeding and slaking of quick lime, followed by the preparation and delivery of a correct milk of lime mixture for water treatment.

PROPORTIONERS

Infilco proportioners are recommended for those plants which will treat water at varying rates of flow. Their application is primarily in controlling the rate of chemical feed so that it is always directly proportional to the flow of water. There are various types of Infilco proportioners to satisfy different requirements.

PRESSURE AND GRAVITY FILTERS

Clean, clear water, essential for municipal supply, is assured by Infilco pressure or gravity filter plants, in capacities from a hundred gallons per day up.

The design of every Infilco filter plant is based upon sound engineering principles backed by over fifty years of experience in equipping many hundred municipal water works, and in building tens of thousands of industrial filters.

TRANSFER SWITCHES, OPERATING TABLES, ROBOTROLS® AND SAMPLING TABLES

Infilco transfer switches provide finger-tip control of hydraulically operated mechanisms. They meet every requirement

of 4-way plugs or piston cocks without their inherent disadvantages. Extreme compactness is obtained by grouping all four separate valves in one body, along with pressure and waste passages.

Infilco operating tables offer both utility and a pleasing appearance. They provide centralized and simplified control for a number of hydraulically operated valves, and at the same time furnish an attractive mounting for the control levers, indicators and gauges.

The Robotrol is a robot filter or softener operator. It backwashes (or regenerates) and returns the unit to service—automatically, efficiently, and without supervision.

Sampling tables furnish a visual check on the condition of raw, treated and filtered water.

INFILCO FILTER UNDERDRAINS

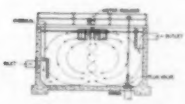
Wagner filter underdrains provide a primary distribution system of a manifold and laterals on wide centers, with distribution orifices along their undersides; and a secondary system of Wagner precast blocks fitting between the laterals. The system fills every requirement for perfect wash water distribution. With manifold and laterals of Transite (an asbestos and Portland cement product) this underdrain is practically everlasting.

CONTROLLERS

Infilco rate of flow controllers automatically maintain uniform rates of flow, prevent dangerous wash rates, and are notable for their accuracy, low loss of head, reset and rate setter features. Infilco water level controllers operate hydraulically controlled valves to maintain basin or tank levels within definite limits.

VORTI-FLOC

The Vorti-Floc promotes economy and efficiency in the chemical treatment of water and sewage. It causes applied chemicals to be utilized fully by bringing the products resulting from chemical reactions into intimate contact with the liquid undergoing treatment.



Rolling the liquid over gently and repeatedly provides a most effective contact between coagulating substances and solids. Finely divided particles are brought together into larger masses which are themselves prevented from depositing by the moving liquid which continually sweeps up the bottom of the basin. All of the chemicals applied are usefully employed in coagulating the solids, and waste is avoided. The solids coagulate and collect rapidly, clarifying the liquid, and aggregate into masses having proper subsiding values. The Vorti-Floc principle has been proved by its use in hundreds of Accelators.

RECARBONATORS

Infilco recarbonators are available for water softening plants where lime is used. This process of stabilizing lime-softened water is effective and inexpensive. The equipment provides for producing, cooling and scrubbing, compressing, drying and applying the carbon dioxide gas to the softened water.

GAUGES AND INDICATORS

Infilco illuminated indicators and indicating, recording, rate of flow, loss of head, and liquid level gauges, furnish visible and permanent evidence of hydraulic conditions, guide plant operation and provide required records. There are various types of Infilco gauges available, with both table and pedestal mountings, to fill every requirement for this kind of equipment.

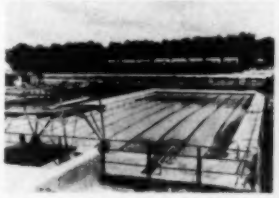
AERATORS

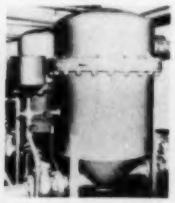
To permit selection of the proper type of aerator to meet conditions of head and space available, character and quantity

of water to be handled, and the results desired—Infilco offers its MultiCone, forced draft, coke tray, floating cone, adjustable cone and cascade aerators.

STELLAR® FILTER RECIRCULATING SYSTEMS FOR SWIMMING POOLS

Stellar Filter Recirculating Systems are outmoding conventional sand filter installations because of smaller space requirements, lower installation costs, and saving of wash water. Stellar Filters are the original diatomite filters to be used on pools and their performance establishes the standard by which





this type of filter is judged. Stellars produce clearer water with less care and without skilled operators, and they cannot be injured by neglectful operation. Other Infilco pool equipment includes: control and regulating equipment, chemical feeders, pool cleaners, pool fittings, testing outfits, hair and lint catchers, sterilizers, heaters, recirculating pumps, and additional specialties.

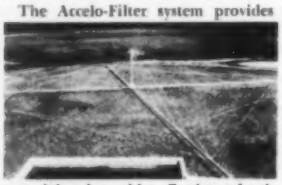
INFILCO SEWAGE TREATING EQUIPMENT

Following are typical examples of Infilco equipment for chemical, biological and mechanical sewage treatment processes. Chemical feeders, slakers, automatic proportioners, and flow meters, common to both water and sewage plants, are described on preceding pages.

AUTOMATIC SEWAGE SAMPLERS

Infilco automatic sewage samplers collect and composite sewage samples at any desired interval from one to twenty times per hour. They are designed to permit sterilization and include a refrigeration unit if desired.

ACCELO® FILTER SYSTEMS



The Accelo-Filter system provides a new and improved method for treating sewage and organic wastes by constant, *direct* recirculation through the trickling filter. This results in repeated inoculation with freshly aerated material and provides effective reduction of the organic content of the biological filter at a considerably higher dosage rate.

ROTARY DISTRIBUTORS AND DOSING SIPHONS

Only Infilco rotary distributors offer so many important refinements such as full opening arm end gates, mercury seal with protective seal ring, with low operating head requirements and uniformity of distribution. Aero-Spray Nozzles provide a fan-shaped variable spray which assures optimum coverage and maximum aeration. Infilco dosing siphons insure perfect operation of distributor mechanism at all flow rates.

CLARIFIERS

Infilco Types WS and PD Clarifiers obtain a perfect balance of the conditions necessary for efficient operation. These Clarifiers are designed with curved scraper blades that gently concentrate and remove settled material with practically no disturbance of the liquid. Accordingly, retention periods may be selected to avoid both septic action and excessive surface scum formation.

VORTI-MIX AERATORS

The Vorti-Mix Aerator is a combined mechanical mixing and air diffusion system which provides more economical aeration for activated sludge treatment. It is not subject to clogging and hence is cheaper to operate and maintain than other diffusion systems.

INFILCO'S "DAYTONA BEACH PROCESS"

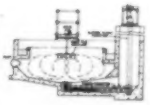
Infilco's "Daytona Beach Process" is one of the most significant new developments in the field of sewage treatment. It is based on the ability of water softening plant sludge (or other similar material) to remove oil and greases and colloidal organic matter. Utilizing the Accelator (Page 2) with Vorti-Mix Aerator, the process accomplishes BOD reduction as high as 80% and produces an effluent averaging only 10 ppm suspended solids, at but a fraction of the cost and space of other primary treatment methods.

AERO-ACCELATOR

The Aero-Accelator with Vorti-Mix Aerator combines intensive aeration with Accelator type circulation to set up the proper conditions for rapid biological oxidation and clarification of liquid wastes or sewage. Dispersion of air throughout the entire mass of "activated slurry" permits a much shorter treatment time than is possible with conventional methods.

VORTEX GRIT REMOVERS

To protect treatment plant equipment, and to reduce the non-digestible load on the plant, Infilco offers the Vortex Grit Remover. The Vorti-Flo Impeller produces controlled velocities which are always right for selective separation and collection of clean grit.

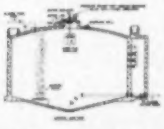


GRIDUCTORS®

The Griductor, for sewage screening and cutting, offers the unique advantages of straight channel installation plus double-end adjustable cutter teeth which may be resharpened and realigned for longer effective life. It is easily installed in existing channels and no difficult framework is required for new construction.

DIGESTERS

Infilco's Type VC Digester provides better digestion and better gas generation. The Vorti-Flo impeller sets up a controlled disturbance in the upper part of the tank to prevent excessive scum formation and to provide the agitation and mixing necessary for optimum digestion. The difficulties of excessive scum formation are avoided and the benefits of proper mixing, circulation and temperature control are obtained with the VC Digester.



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DEEP WELL PUMP TESTING*

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THE general theory and use of hydraulic and electrical instruments to test pumping plants have been the subject of many fine articles. The matter is also amply covered in textbooks and in some very excellent bulletins prepared by pump and instrument manufacturers. Hence, this article will be confined to the specific field equipment, methods and practices employed by the Pacific Gas and Electric Co., in testing the pumps of its customers in northern and central California. For the same reasons, formulas will be held to the minimum. Wells, as a separate subject, will be only partly covered.

The pump test service was started in 1923 by what was then the San Joaquin Light and Power Co., now a major division of Pacific Gas and Electric. At present nine two-man crews, strategically located from Bakersfield to Marysville, Calif., are equipped with hydraulic and electrical instruments to conduct field tests, all of which are made at the customer's request in the form of a signed application. A total of more than 70,000 tests have been made to date. Each test involves field measurements and notes, a typewritten report to the customer (with any recommendations needed), and personal delivery or a letter of transmittal. The letter usually contains power usage figures, data on the total amount of water pumped and unit cost figures. As the work is seasonal, during the summer farm irrigatiation season the crews are usually one or two months behind the test applications. The company conducts free tests because a customer with inefficient pumping equipment will frequently believe that the poor performance of the pump and his increasing power costs are due to improper electric service or excessive rates.

Essentially, the tests yield reasonably accurate, usable information about the pumping plant, which the customer can employ to maintain minimum pumping costs, maximum flow or both. Unless the customer represents a large organization rather than an individual water works operator or farmer, he can usually not obtain this service elsewhere except at considerable cost, if at all. More than 6,000 tests are made each year, and in 1948 approximately 5.2 per cent involved water works pumps. It is the desire of the company to be of maximum service to all classes of customers—agricultural, industrial or water works. As all but a very few of the company's 50,000 agricultural customers have no engineering service available, however, the farmer receives about 87 per cent of the tests made annually.

Testing Procedure

The testing of a deep well turbine in its well requires not only proper instruments but a tester with sufficient knowledge of the characteristics and limitations of these instruments to obtain maximum accuracy when employing them, together with sufficient knowledge of pumps, motors and wells to interpret the data obtained. In order to be of service to the pump owner, the tester does not require instruments of laboratory accuracy. The time and expense involved in installing an orifice, nozzle or weir would seldom be justified, and, unless a great many conditions of the individual installation were taken into account, these instruments would be no more accurate than the pitot type. Fig. 1 shows schematically the test values for a deep well turbine delivering water to an elevated tank in a water system. Most of the terms are self-explanatory. Although the water-bearing stratum (there are often several) above the standing level may provide insufficient water to affect the well water levels materially, the falling water it produces frequently interferes with water level measurements. When the standing water level has been measured, the pump is started. In some areas the pumping level will stabilize in a few minutes, while in others it takes hours. Readings made while the water level is dropping rapidly are generally not simultaneous and also the test is not sufficiently typical of operating conditions to be of much use. When the level has stabilized, further test readings are taken. Assuming the speed to be relatively constant, figures for total lift (pumping level and discharge level), capacity (gallons per minute) and horsepower input to motor are required to determine the overall plant efficiency.

Where the distance to water is very small, the water level can often be seen and measured with a tape line. Usually, however, a sounder tip is connected through a reel of flexible insulated wire to a voltmeter (or milliammeter) and a battery, the latter being grounded to the pump or well casing. The battery voltage is 4.5-45 v. When the sounder tip is lowered until its copper wire touches the water surface, completion of the circuit produces an indication on the voltmeter. The wire is then marked at the reference, usually the centerline of the pump head discharge, and the wire is then raised and measured with a steel or fabric tape. If the tip is lost, a new one is readily connected by a hand splice and taping.

Use of Air Line

Sometimes water falling from an upper perforation gives an unsteady indication on the meter, and the exact point of touching the pumping level cannot be determined. In this situation an air line can be employed. Also there may be so much oil on the surface that the electric circuit cannot be completed. More than 16 ft. of oil (bearing leakage) has been found above the water in wells, although that figure is above average.

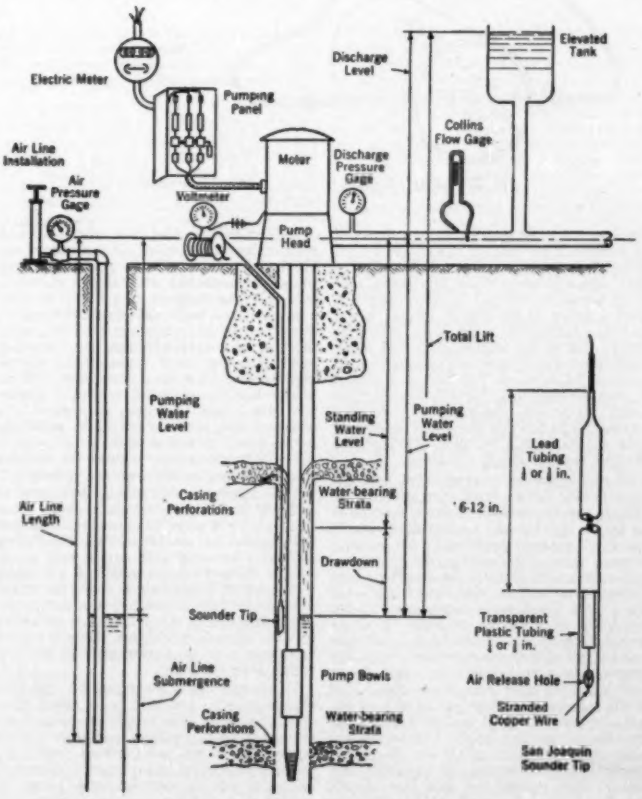

Fig. 1. Test Values for Deep Well Turbine

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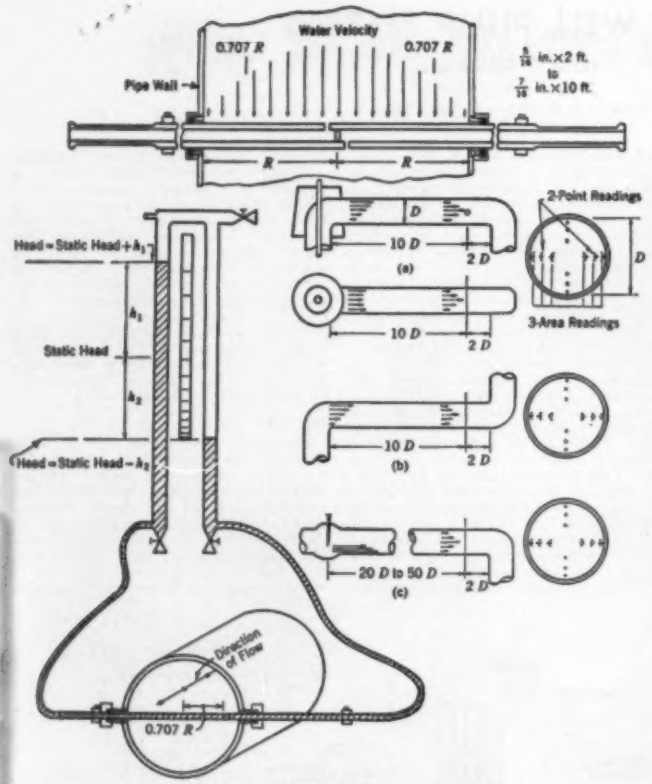


Fig. 2. Collins Flow Gage With Water Manometer

The lower specific gravity of the column of oil permits it to float on top of the water, giving it an upper surface somewhat higher than, and a lower surface far below, that which would be reached by water alone. A reading taken at the top of the oil would therefore indicate a water level somewhat higher, and at the bottom of the oil much lower, than true hydrostatic pressure would produce. Again an air line can be employed to provide true water levels. Its effective length minus the maximum gage reading (converted to feet) is the water level. Air lines are extremely reliable, provided the effective vertical length is known.

Often the standing water level, but not the pumping water level, can be obtained with an electric sounder. When a permanent air line is in place and a satisfactory standing level measurement with the electric sounder is possible, adding the maximum gage reading in feet to the standing level measurement will provide the effective air line length. Checking is necessitated by the possibility of breakage or leaks. If other means have failed, testers have sometimes lowered an electric-sounder line—with the sounder tip removed and an open sleeve over the bare wire end—down the inside of the column (which is free of oil) to obtain the standing level and thus determine the effective air line length. Unless handled with great care, for relatively short distances, there is danger of wrapping the sounder line around the tube line or entangling it in a "spider," when such tube line supports are used. A portable air line of rubber hose can be used in the normal well casing space when no permanent air line is available. As the length used can, of course, be measured while out of the well, it is only necessary to raise it 2-3 ft. after a measurement in the well to see if the gage drops an equivalent amount, thus indicating that the line is suspended free and not coiled up at an obstruction. For some hoses, stretch may become important when over 100 ft. of light air line is used. One line of single-ply hose (used to reduce diameter) was found to have a stretch of 19 ft. at 350-ft. suspension. Correction tables which proved fairly accurate were prepared for various lengths suspended and amounts submerged.

The capacity cannot usually be measured with the same degree of accuracy as other values, but the water level sometimes cannot be obtained at all because of insufficient clearance between well casing and pump column, flanged column couplings, a crooked well, mud or debris lodged above the water level, water level below bowls of nearly the same diameter as the well casing, or baffles installed around the column. The drawdown is a measure of the performance of the well rather than the pump.

Discharge head, measured by the discharge gage, is generally used rather than discharge level (the vertical distance from the pump head discharge centerline to the water level of the tank), which credits the pump with friction losses past the discharge gage and also the velocity head. Losses in suction pipe, column and head elbow are rarely credited, due to inaccessible gage connection locations when the pump is in a well. Accuracy on levels is limited only by the accuracy of the measuring tape and the pressure gages, the latter being periodically calibrated on a dead-weight tester.

Motor Input

Motor input is measured from the speed of rotation of the meter disc and from the constant applying to that particular meter, multiplied by the constants of the potential and current transformers, if used. Although rules require the electric meters to be accurate only within 2 per cent, the average error will be considerably less than 1 per cent. Motor (and pump) speed is measured with a chronometric speed indicator or revolution counter and stopwatch, either through a hole in the motor cover or with the cover removed. Centrifugal type tachometers are only satisfactory for continuous field use if handled very carefully and frequently calibrated. The voltage and current are measured at the switch box, generally using a split-core volt-ammeter. The voltage between phases is measured to determine if the motor is receiving proper potential, and the voltage to ground is checked to determine if any conductors are accidentally grounded. Current measurements show any possible current unbalance. A small current unbalance is relatively unimportant and may be due to voltage unbalance caused by a single-phase load on the same transformer bank which supplies the motor. Serious unbalance may mean damaged motor windings or an improper rewinding job and should be investigated further to forestall later burnouts, as well as to reduce energy losses. Calculation of horsepower or kilowatt input from voltage, split-core ammeter readings and estimation of the power factor is only relatively accurate and should be used merely for rough measurements or when the wattage cannot conveniently be directly measured.

Capacity Measurement

Capacity is measured with a pitot type instrument, either the Collins flow gage or the Hall tube described later. With a good piping arrangement, readings approach an accuracy of 3 per cent. Figure 2 shows, at the top, a sectional view of a Collins flow gage in a pipe. It can be moved to measure the velocity at any point across the diameter and during such movement has a constant area in the pipe so that it does not cause changes in velocity distribution. The Collins tube measures velocity by converting the water velocity (V), in feet per second, into head, in feet. One orifice faces upstream and produces a pressure equal to static pressure plus the head due to velocity (h_1). The other orifice faces downstream and produces a pressure equal to static pressure minus the head due to velocity (h_2). In the latter instance, all of the velocity is not converted, hence the constant k_3 used in the following formulas:

$$V = \sqrt{\frac{2g\left(h_1 + \frac{h_2}{k_3}\right)}{1}}$$

$$h_1 = \frac{V^2}{2g}, \qquad h_2 = \frac{V^2}{2g} k_3$$

In Fig. 2, D is the inside pipe diameter and R, the inside pipe radius.

Readings taken with the water manometer connected to this tube do not depend on measurements of static head, but the distance between water levels in the glasses is equal to nearly twice that due to the head produced by one orifice alone. The scale used to read velocity is therefore marked accordingly. The specific gravity of the water does not affect the velocity readings. Obtaining average velocity by multiplying centerline veloc-

ity by a constant is an extremely rough method, particularly with the lengths of pipe available at most pumping plants. It has been found that if fairly uniform velocity distribution exists (as shown), the average of velocities measured at two locations $0.707R$ from the center on either side of the pipe center will give results of reasonable accuracy. The tube is reversible, two readings are taken in each position and the average velocity is the average of four readings. This reversal will show up, by unbalance, any orifice stoppage or air pocket. The center velocity, although not used in the calculations, is also measured to give an idea of the shape of the velocity distribution curve and thus to decide whether a two-point, three-area or five-area traverse should be used. For greater accuracy, readings may be taken at three points on each side of center, as shown at Fig. 2 (a), right. These points are in three annular rings of equal area and the points are located, not at the midpoint of the ring, but so that each point separates the ring itself into two equal areas. For greater accuracy, five areas (five points on each side of center) may be used. If required, readings can also be taken at an axis normal to the above points (as indicated by the dots in Fig. 2, right). The axes need not be vertical or horizontal, but at the best angles to survey the velocity distribution of the pipe. For a three-area traverse, the reading points are at distances $0.204D$, $0.354D$ and $0.456D$, on either side of center. Five-area traverse readings are at $0.158D$, $0.274D$, $0.354D$, $0.418D$ and $0.474D$. Distances are given as functions of D because pipe tables and measurements generally list diameter instead of radius. With small pipes, care must be taken to keep the orifice out of the bushing or pipe wall.

The velocity scale is based on $V = \sqrt{2gh}$, but h represents nearly twice the h of an ordinary pitot tube (*see* Fig. 2). Capacity, in gallons per minute, equals $k_2\ 2.45\ D^2V$. The constant, k_2, is determined by calibration for various pipe sizes and includes the correction k_1 and the partial effect of the tube area in the particular pipe size manometers are used, and for velocities used. For lower velocities, 3- and 4-ft. above that of the latter, a vertical mercury manometer is employed. Pipe sizes below 3 in. are not desirable. Tubes are in 2-ft. and 3-ft. lengths in the 5/16-in. size and in lengths up to 10 ft. or more in larger sizes. Depending on the tube diameter used, ¼- or ¾-in. I.P.S. ("Iron Pipe Size" standard) holes are tapped in the pipe.

Fig. 2(a) shows the plan and elevation of a typical pump head and discharge pipe, indicating the effect of the elbow and of the shaft tube on velocity distribution. It is obvious that readings taken in the discharge pipe right next to the pump head will have a greater than normal error, which would be true even if three or five points were used. At 10 diameters past the head and at least 2 diameters ahead of the next obstruction, a two-point or three-area traverse will generally be of ample accuracy. A typical example of unbalanced velocities produced by an elbow is illustrated in Fig. 2 (b). Figure 2 (c) shows why it is so difficult to obtain accurate flow readings past a partly closed valve, such as is sometimes used to limit pump capacity to a reduced well capacity. Although it is *theoretically* possible to obtain capacity accurately, even when a heavy unbalance of velocity exists, by taking a great number of readings on each diameter and by using a great number of diameters or axes, this method does not work in practice and a more suitable location had better be chosen. A two-point reading, using only a somewhat battered length of pipe temporarily connected to an outlet valve, will provide accuracy superior to a hundred traverse readings at a section with heavy unbalance. This statement is true of all types of pitot tubes, as well as of other instruments.

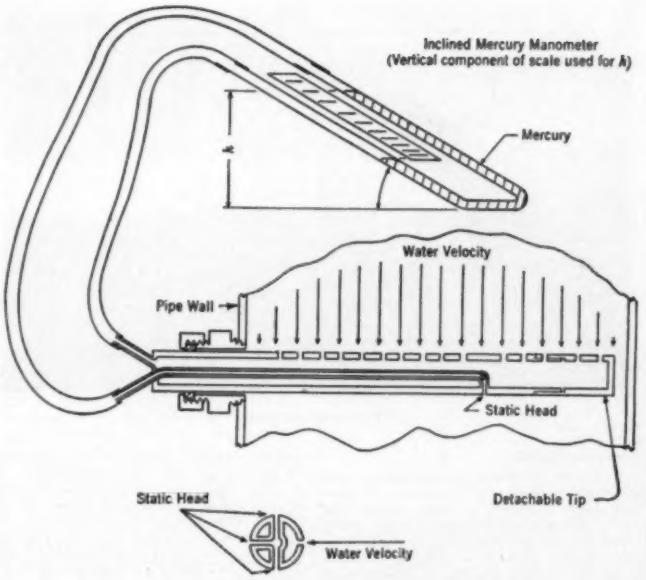


Fig. 3. Hall Tube Connected to Mercury Manometer

Approximately one-half of the 50,000 agricultural pumps, representing 1,000,000 hp. of connected load on the system, are served by the San Joaquin Power Div. of the company. In this area, the Hall type of pitot tube is used. While the two companies were still separate, San Joaquin adopted the single-reading tube instead of the Collins tube. Actually both instruments in proper hands produce very satisfactory results. Figure 3 shows a rough schematic cross section of a Hall type tube in a pipe and connected to an inclined mercury manometer. The tube shown has detachable tips covering pipe sizes 6-12 in. and, when placed in proper position in the pipe, is not moved from side to side or reversed. Three holes transmit static pressure to one side of the manometer, while a number of holes facing the direction of flow average the heads produced by the velocities which vary from side to side of the pipe. The San Joaquin Power Div. employs a mercury manometer with this instrument, the manometer being inclined, to increase the differential reading. Several small spirit levels are attached to the manometer itself. Each one, when in turn leveled by adjusting screws in the base, provides a separate convenient multiplying factor for the mercury differential on the incline to obtain the vertical component. A water manometer can, of course, also be used with this tube. Velocity equals $k\sqrt{2gh}$, k referring to the individual calibration of the specific Hall tube used. In practice, a scale proportional to $\sqrt{h}$ is used,, and this reading is multiplied by the pipe area, in square inches. Correction for the individual tube and the particular pipe size and capacity is then made by adding or subtracting a value of "gpm." determined by calibration. One ¾-in. I.P.S. hole is required. For both the Hall and Collins instruments it is important that the pipe at the point of velocity measurement be full, carry as little air as possible and be free of mud or other area-reducing deposits or objects.

Figure 4 shows a Hall tube connected to an inclined mercury manometer. Note the shutoff cocks to prevent loss of mercury while connecting up, and the three valves to remove air from the tube. One valve is near each hose bib and one is on the main body of the tube. Also note the adjustable clamp to position the tube. These parts were omitted form Fig. 3 for simplicity and clarity. The adjustable tips are shown at upper right.

A more-or-less standard type of pitot tube and water manometer used by the San Joaquin Power Div. for pipes over 12 in. in diameter, is shown in Fig. 5. With it, readings can be taken at three, five or more points on either side of center. In other divisions, various lengths of standard Collins tubes are used for this purpose. A standard type of pitot tube is also supplied by Collins for the use of the other crews where it is not convenient to pass the standard Collins tube through both sides of the pipe. As few water works installations in this territory use pipes greater than 12 in. in diameter, these long tubes are employed mostly for reclamation and irrigation projects pumping large volumes of water through relatively small lifts. In this field, pipe sizes of 4 ft. and capacities of 40,000gpm. are encountered. Current meters have measured capacities of approximately 1,000,000 gpm., representing the discharge of ten low-lift pumps. Separate pump capacities were determined. Measurements of kilowatts, volts and amperes were made for each 2,300-v. motor (225-550 hp.) and water elevation gages were checked with a surveyor's level. The company has a hydraulic laboratory at Fresno—designed, built and operated by the San Joaquin Power Div. —where field instruments can be tested against orifices, a weir and volumetric measurement. A motor-driven pump discharges water through selected pipe sizes. E. J. Griffith, Power Engr. of the Fresno office, has given considerable time to the design, construction and operation of this laboratory.

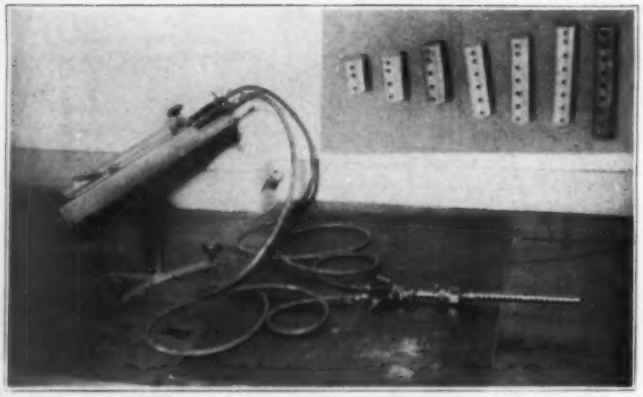


Fig. 4. Hall Tube Assembly

Pump Test Reports

The pump test reports emphasize total lift, water pumped and horsepower or kilowatt input to motor to determine overall plant efficiency. These items, with pump speed, are the elements of pump and motor performance. The yield of the well, expressed as "gpm." per foot of drawdown, is a measure of well performance which allows comparison with other wells in the same area or with the same well at other capacities.

Water temperature, in areas where sufficient history is available, gives some indication of which strata supply most of the water. A change in the temperature of a certain well between tests may indicate a loss of supply from one stratum due to well collapse. The use of this information requires considerable knowledge of the specific area. Water temperatures in the company's area of operation vary from 60° to 100°F.

A combined index of pump, motor and well performance is given by kilowatt-hours per 1,000 gal. of water pumped. This ratio is valuable in comparing pumping units on the same system and in estimating power usage for new plants.

When overhauling or new equipment is needed, the customer is urged to consult his pump dealer and well expert for final information, as it is not the function of the pump tester to recommend the particular type, size or manufacture of equipment to be installed, or the specific type of overhaul to be performed.

Special Problems

As motor and pump manufacturers have in general done an excellent job of providing information on the routine care and maintenance of motors and pumps, and as some of the larger water works organizations have engineers and maintenance men of great experience, only a few brief notes referring to special problems will be discussed.

1. The better the piping arrangement used for testing, the more accurate will be the test results.

2. The ease with which the pitot type of tube can be installed, the water level obtained and horsepower input measured will determine how much testing a crew can do for a customer in one day's time. Under difficult conditions, only two tests may be made per day, while otherwise four to six tests are possible. Figure 8 shows two methods of discharge pipe layout which provide maximum accuracy and minimum test time to measure capacity. Holes for the pitot tube are drilled by the test crew about ten diameters past the pump, leaving two diameters ahead of the next fitting. If the pipe is below ground, a permanent pit, extending across it at least 3 ft. on either side (more for pipe above 12-in. diameter), to a depth of 6 in. below the pipe bottom and 3 ft. wide, will allow rapid instrument installation. Where adequate room exists, a head of perhaps 10 or 20 ft. due to water remaining in such a pipe is not prohibitive to installation.

Fig. 5. Pitot Tube Assembly

3. Mueller type cocks permanently installed in the pipe render it unnecessary to shut down the pump for tube installation. Such cocks, however, are not particularly desirable for measurements in small pipes as they generally will project into the pipe, causing disturbed flow. In larger pipes, great care should be taken in tapping and in installing the cock, to prevent excessive protrusion into the pipe. Also, where two cocks are used for a Collins flow gage, they must be in alignment.

4. A water meter is of great benefit. It allows a check of capacity at times of the year when the water table may be at an extremely low level and the pump test crew is not immediately available. If several pumps deliver water to a master meter, the addition of individual meters will indicate the failure of one pump. The meter should be installed approximately where the check valve is installed in Fig. 6 (a) or the gate valve in Fig. 6 (b), and these two items should be moved two to five diameters farther away from the pump. Meters without calibration for long periods lose their accuracy, however. Often checks can be made simultaneously using primary measurement with an accurately measured reservoir, the Collins flow gage or Hall tube and a water meter.

5. A means of access to the well casing should be provided either in the pump head base or directly under it, or, better yet, by means of a capped pipe, as in Fig. 6 (b). The pipe should be welded to the well casing or otherwise securely fastened and sharp edges smoothed. Public health agencies prefer a capped pipe to an open hole in the pump base.

6. Where previous difficulty has been encountered in obtaining the water level, because of insufficient clearance, falling water or excessive oil on the water surface, a permanent air line should be installed and its effective length plainly marked in the pumphouse. Water conditions will dictate whether steel or copper is used. With copper, if compression joints are used, they should also be soldered; otherwise vibration may produce leaks, rendering the air line useless. The customer may desire to have a direct-reading gage and hand pump permanently connected for his own readings, but the test crew will use their own calibrated gage. The air line should be securely fastened so that the attachment of a gage will not cause the line to drop down the well, and it should be sufficiently clear of the pump head to allow turning the gage for connection. If water level and discharge pressure records are kept during the summer low period, the same total-head condition can be duplicated in the winter—when more time is usually available for testing—provided that the discharge pressure can be raised by the use of a valve, or lowered by the use of a large drain valve, as required.

7. Information on the diameter and depth of each size of well casing (if more than one is used), the pump setting, bowl length, length of suction pipe and existence or absence of a strainer should be available in the pumphouse for the benefit of the tester in obtaining water levels and properly interpreting them. A well log, with the location of casing perforations, is of considerable use when reliably prepared.

8. Fuses should be of the proper size and should make good contact with the jaws. The overload relay mechanism should be inspected periodically for free movement which might be hindered by mud daubers and mechanical damage. Thermal relay heaters should be installed only in the size proper for the motor rating and the air temperature where the motor is located. Motors under average temperature and air circulation conditions can generally be safely over-

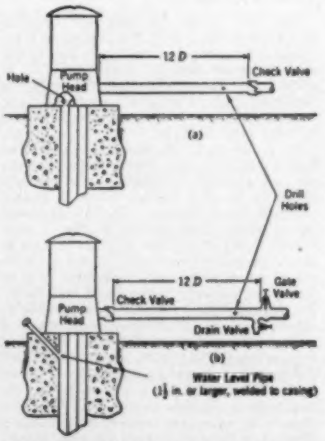


Fig. 6. Preferred Installation Methods

loaded 15 per cent, but when in pits or other confined places, even the full rated load may be too much for motor safety.

9. A situation exists with regard to motor protection which is not universally understood and which will, therefore, be very briefly covered here. Two heater elements in the starter will protect a three-phase motor against practically all fault or overload conditions of excessive current occurring on the motor, or secondary, side of the power transformers. Under certain conditions, applying to transformer connections used in many parts of the country, the loss of one primary conductor (due to accidental breakage) will produce a current from two to three times normal in one motor conductor and perhaps only slightly more than normal current in the other two conductors. If this heavy current occurs in the unprotected conductor, and, as often happens, the motor does not stall and the current in each of the other two conductors is not enough to trip the starter, the motor is not protected. If the motor has already been carrying full load, it will probably burn out in 20-60 minutes; otherwise, a somewhat longer duration of the primary outage might be required for a burnout. Each year a large number of motor burnouts are encountered by the company for this reason. It is not practical, from the standpoint of the best all-around service and lowest rates to the customer, for the company to attempt to provide protection against loss of a primary wire on the primary, high-voltage side. The loss of one water works motor could be very critical during the summer heavy-load period, not to mention the expense of rewinding the motor. A thermal relay should be provided in the unprotected conductor. Thermal type fuses in the switch box will perform the same function, but it would be ideal to use three thermal relays and three thermal fuses. Electrical dealers can recommend the proper sizes of each.

10. Often a customer installs a new pump or new set of bowls with guaranteed performance values and requests the company to make a test to determine if the guarantee has been met. The company is ready to do so, but the tester will not advise the customer to accept or reject the pump as a result of the test. Also, when comparing test and guaranteed values, instrument accuracy limits must be considered.

Summary

1. Pump testing assists the customer in obtaining maximum capacity at maximum efficiency with minimum energy usage and minimum motor size.

2. Both Collins flow gage and Hall tubes, in proper hands, give satisfactory accuracy.

3. Although ten diameters after and two diameters ahead of elbows or other flow disturbers are desirable, satisfactory results can be obtained with half and sometimes one-third of these distances when care in positioning the instrument is exercised.

4. When water works customers are installing new plants or revamping old ones, it is an excellent time to rearrange piping for ease of capacity measurement. When the pump is out of the well, it is a simple matter to provide an entrance to the casing (if not already there) to allow water levels to be obtained.

5. A water meter properly located and periodically calibrated is of great assistance in taking measurements of capacity during the year and shows up decreased capacity due to wear or lowering of the water table.

6. Where exeprience shows that water levels cannot be easily obtained by the electric sounder, a permanent air line, properly measured and secured, should be supplied.

7. Information on well casing sizes and depths, pump dimensions in the well and effective air line lengths should be available near the pump.

8. All three-phase motors driving such important equipment as water works pumps should have three-element protection.

9. The Pacific Gas and Electric Co. is not always able, with existing test personnel and equipment, to test all plants as requested, particularly during the summer irrigation season. Most farms cannot provide a place to receive pumped water during the winter without damage resulting, while most water works can easily find space in their storage to allow pumping during the winter for an hour or so. Hence, it is preferable to test water works pumps during the winter, acceptance tests being an exception. Some larger water utilities may prefer to do part of their own testing.

10. Pump testing has resulted in higher average overall plant efficiency and has reduced power costs. Analysis of tests made for the company's farm, water works and other customers, and comparisons of their power accounts, show that thousands of dollars are saved each year as a result of the pump testing service.

CALCULATION OF PIPE LENGTHS FOR INCLINED DIAGONAL RUNS

CHARLES FRICK

Water works men may find the following formulas interesting and helpful in figuring lengths of pipe and tie rods on inclined diagonal runs.

The formulas are also useful in finding the approximate angle of fitting, theta (θ), required (when bell and spigot pipe and fittings are used) when the dimensions in three planes have been decided upon.

The evolution of the formulas (see illustration) are also given in case the principle of revolution to a vertical plane may have further advantages in similar problems.

The subtraction of the center to end of spigot and center to back of bell taken from D gives the true length of pipe required.

Sketch Explanatory of Formulas for Lengths of Pipe for Diagonal Runs and Angle of Fittings

A.—When measurements in three planes are known, then

$$D = \sqrt{A^2 + B^2 + C^2} \qquad \text{Formula I}$$

$$L\ (\theta)^{-1\text{deg}} = \frac{\sqrt{A^2 + B^2}}{C} \qquad \text{Formula II}$$

Example: Let A = 5′6″, B = 3′0″, C = 14′9″
Find (θ) and length of pipe required on 8″ line.

$$D = \sqrt{(5.5)^2 + (3)^2 + (14.75)^2}$$
$$= \sqrt{30.25 + 9 + 217.56} = 16.025' \text{ say } 16'0''$$

$$L\ (\theta)^{-1\text{deg}} = \frac{\sqrt{(5.5)^2 + (3)^2}}{14.75} = \frac{\sqrt{30.25 + 9}}{14.75}$$
$$= \frac{\sqrt{39.25}}{14.75} = \frac{6.265}{14.75} = 0.42474$$

$L\ (\theta) = 23° +$ and a one-sixteenth curve may be used.
Length of pipe = D — (C to E of S. + C to B of B.)
= 16′0″ — (2′1″+) = 13′11″—

B.—When measurements in two planes are known and angle f fitting (θ) decided upon, then

$$D = \sqrt{A^2 + B^2} \times \text{Csc}\ (\theta) \qquad \text{Formula III}$$

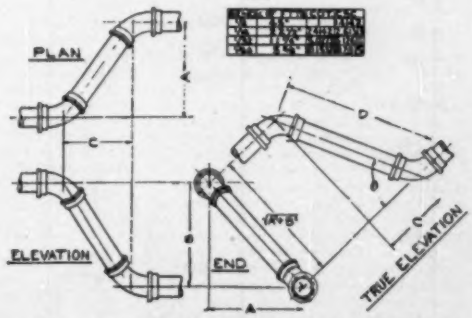
$$C = \sqrt{A^2 + B^2} \times \text{Cot}\ (\theta) \qquad \text{Formula IV}$$

Example: Let A = 8′0″, B = 9′6″, (θ) = 45°
Find—C and length of pipe required on 12″ line.

$$D = \sqrt{(8)^2 + (9.5)^2} \times \text{Csc}\ 45°$$
$$= \sqrt{64 + 90.25} \times 1.4142$$
$$= 17.56' = 17'6\tfrac{3}{4}''$$

Length of pipe = D — (C to E of S. + C to B of B.)
= 17′6¾″ — (2′1⅞″) = 15′4¾″

$$C = \sqrt{(8)^2 + (9.5)^2} \times \text{Cot}\ 45°$$
$$= \sqrt{64 + 90.25} \times 1$$
$$= 12.42 \times 1 = 12.42' = 12'5''$$



Sketch Explanatory of Formulas for Lengths of Pipe for Diagonal Runs and Angle of Fittings

PIPE BENDING CHART*

This chart will be found useful for determining the average radius of bend that should be given to common forms of pipe bends, numbers 1, 2, 3, and 4, as shown at the right, column E.

Also, knowing the radius of bend, the size of pipe, and the form of bend, column D gives expansion allowance of that bend.

For example a 5 in. pipe was bent to a radius of 40 inches, the bend being a common U-bend as shown by No. 2 in column E. What expansion may be allowed?

The dotted line drawn across the chart shows how the chart is used. Run a straight line through the figure 5, column A, and the 40, column B, and locate the intersection with column C. Then from the point of intersection run over to the mark in column E opposite the figure 2 and the intersection through column D gives the answer as 1.5 in. expansion allowance.

If the size of pipe were the same, 5 inches, the average radius 40 inches and the bend were a "No. 4" bend, the expansion allowance would be 3.7 inches. If the bend were a "No. 1" bend the expansion allowance would be 0.75 in.

Similarly if the expansion allowance is already known, if the form of bend is known, and if the size of pipe is known, the average radius to which the bend should be made may be determined. In other words, knowing any three of the four factors given in columns A, B, D and E the fourth or unknown factor is easily determined by following the method as explained above.

The chart is based upon these rules:

For Bend No. 1—Square the average radius of bend in inches and multiply by 0.0026 and then divide by the outside diameter of the pipe in inches.

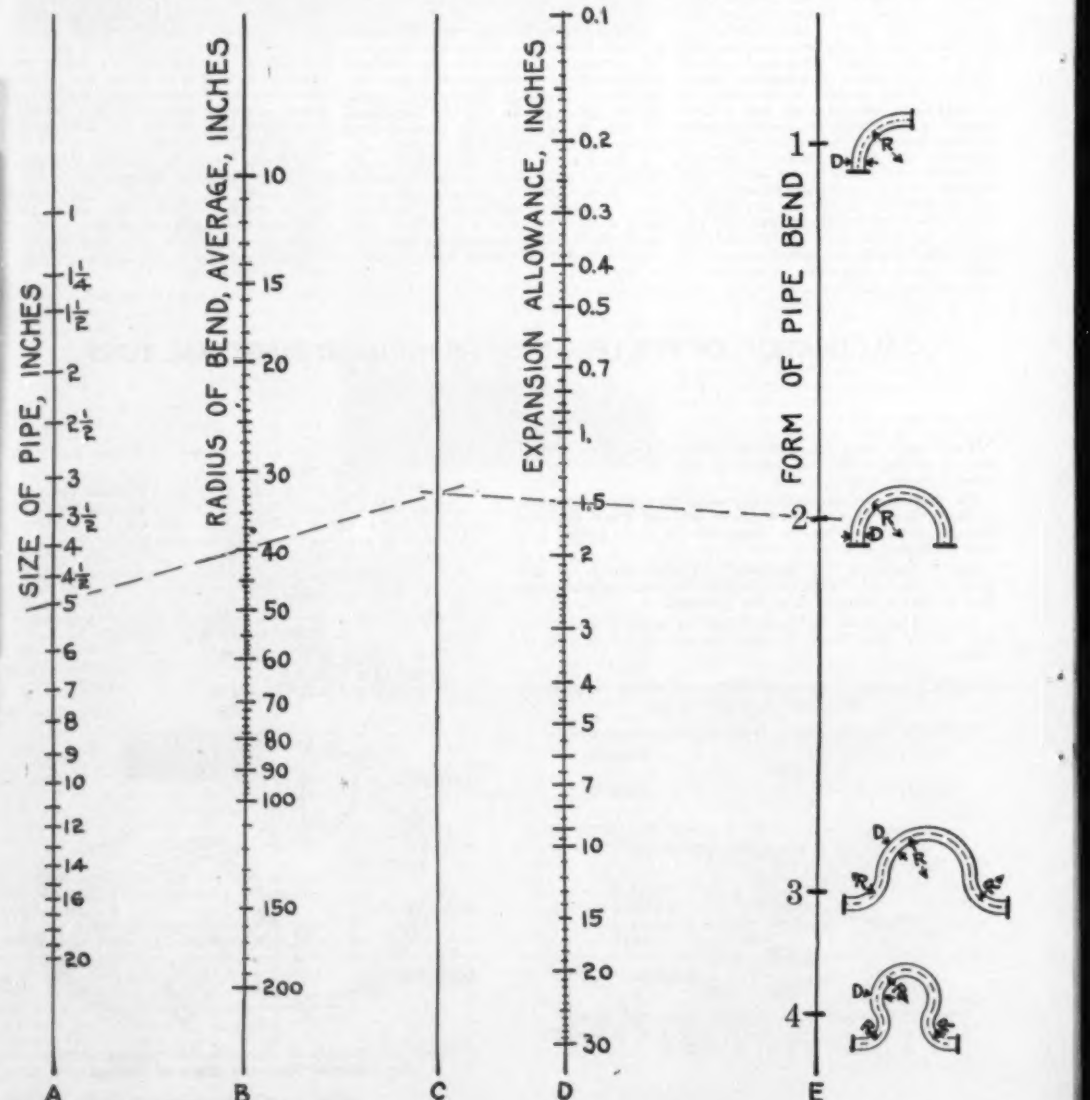
Bend No. 2—Same as No. 1 but multiply by 0.0052.

Bend No. 3—Same as No. 1 but multiply by 0.0104.

Bend No. 4—Same as No. 1 but multiply by 0.013.

In the chart all of these operations are already performed—the radii are squared, exact outside pipe diameters are employed, and the proper factors are used.

*Contributed by W. F. Schaphorst, M.E., Newark, N. J.



WATER USE BY AIR-CONDITIONING EQUIPMENT*

LEWIS L. BARNES
Chief Engineer
Carrier Atlanta Corp., Atlanta, Ga.

BECAUSE of the growth of the air-conditioning industry, water use by air-conditioning equipment has become increasingly significant. Some municipalities have been forced to invoke restrictive measures; others may soon find they must take similar steps; but still others may never find it necessary to follow this course. It is therefore appropriate to take a clear view of the subject at this time in order to evaluate its importance and study corrective measures if applicable.

The term "subject" is used rather than "problem" because the consumption of water by air-conditioning equipment is not necessarily a problem unless local factors make it one. A study of this water usage should be entirely local in scope, and since so many local conditions complicate or simplify the problem, this discussion will, of necessity, be held to generalities, with no attempt being made to recommend procedure for purely local situations.

Condensers

All air-conditioning systems employing mechanical refrigeration require some means of cooling the compressed refrigerant gas in order to condense it back to the liquid

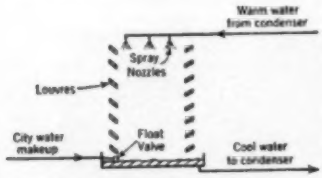


Fig. 1. Atmospheric Cooling Tower

state. One of the most popular methods is the use of the air-cooled condenser, but unfortunately its overall efficiency is so low that it is not generally practical except in very small installations.

On larger installations, it is quite common to use a water-cooled condenser, employing the public water supply as the cooling medium. This device usually consists of a shell-and-coil type of heat exchanger, with water passing through the coil and cooling the refrigerant gas which comes in contact with the outside of the coil. In this process, the temperature of the water is raised to a point at which it is no longer useful as a cooling agent and must be rejected in favor of water at a lower temperature. There is obviously a continuous flow of water through the condenser while the equipment is in operation, amounting to approximately 1.5-2.5 gpm. per compressor horsepower at full load. It is apparent that this method can result in the wasting of large quantities of water which has undergone no other change than that of a 15-20°F. rise in temperature. For example, a 10-hp. air-conditioning compressor, using city water at the rate of 2.0 gpm. per horsepower, consumes 20 gpm., 1,200 gph. and 9,600 gal. or 1,270 cu.ft. per eight-hour day. These figures may not be impressive to those accustomed to thinking in terms of millions of gallons per day, but with a multiplicity of installations, the water consumed can become a significant load on

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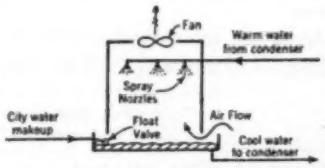


Fig. 2. Induced-Draft Cooling Tower

the city water mains. Whether this load is desirable or undesirable depends on local conditions, but it must be borne in mind that it generally occurs during the summer months and may coincide with other peaks.

The air-conditioning installation just described is relatively low in initial cost to the owner, but, depending on local water rates, could be quite expensive to operate because of the high water consumption. Installations of this type are usually equipped with an automatic water-regulating valve to insure against using more water than is required under less than the maximum load. It has been the author's experience that these valves are adequate for adjusting water flow to meet load conditions but should not be relied on to effect complete closure during shut-down periods. It must not be overlooked that, in certain localities, the disposal of waste condenser water constitutes just as great a problem as does the supply of this water in other localities.

The wasting of condenser water could sometimes be objectionable on account of inadequate supply or disposal facilities, high costs, high initial temperatures, poor chemical characteristics and other factors. It is well to consider, therefore, some of the most common means of combating this problem.

Conservation Devices

The water-cooled condenser described previously can be used in conjunction with a cooling tower or spray pond, which, if properly designed and installed, can recapture approximately 95 per cent of the water otherwise wasted. This saving is accomplished by re-cooling the warm water discharged from the condenser and returning it to the condenser by means of a circulating pump.

The atmospheric cooling tower (Fig. 1) depends entirely on natural wind and air currents to cool the condenser water effectively. It is suitable for location only in places where free and unobstructed air flow is available. Many installations of this type have failed to produce the desired results because the tower was located in a light court or on the lee side of some obstruction.

The induced-draft cooling tower (Fig. 2) is equipped with a motor-driven fan to create its own draft. This type can be located in many positions which would be unsuitable for the atmospheric tower, but obviously its initial cost is greater.

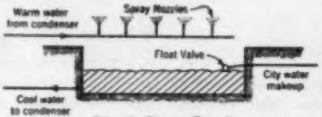


Fig. 3. Spray Pond

The spray pond (Fig. 3), commonly used as a water conservation device, has certain advantages as well as disadvantages when compared with cooling towers. Job conditions should govern the choice.

The cooling towers and spray pond will perform the desired task of water cooling with varying degrees of efficiency, depending on local conditions. They are all readily suitable to existing water-cooled installations, with the adaptation usually consisting of simple piping changes and the addition of a circulating pump. It should be remembered that the addition of the water-circulating pump will increase the use of power, a fact which must be considered when evaluating operating costs.

The evaporative condenser (Fig. 4) is one of the most efficient means of condensing with minimum water requirements. In this device, the refrigerant gas is cooled directly by a combination of air and spray water passing over the condensing coil. Only one heat transfer is necessary (gas to water and air), as contrasted with the cooling tower or spray pond, which require two heat transfers (gas to water, and water to air). The evaporative condenser is very compact and frequently can be placed in locations which

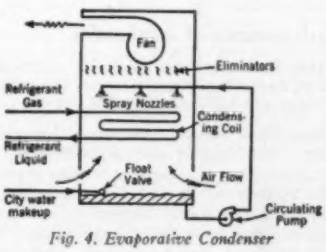


Fig. 4. Evaporative Condenser

are not practical for cooling-tower installations. On new installations, the evaporative condenser compares favorably in first cost with cooling towers and spray ponds. If water-conserving equipment is to be applied to existing water-cooled equipment, the cooling tower is usually cheaper than the evaporative condenser, in that the tower installation continues to utilize the existing water-cooled condenser.

From the viewpoint of those in the business of supplying water, the subject can be summarized by stating that:

1. The water load imposed by air-conditioning equipment can be attractive to those systems which have ample water for sale during the summer months.

2. This load can be unattractive to those systems which have a deficiency of water in the summer if the return from water sales will not justify additional investment in plant or distribution facilities.

Water systems which cannot stand this load imposition must work out the problem through local channels. Some cities have been forced to invoke restrictive ordinances to prohibit the indiscriminate wasting of water. All ordinances of this nature should be flexible enough to prevent undue hardship. Some thought should be given to the possibility of instituting demand charges to compensate for the standby facilities when no water is being used.

THE ANTHRACITE EQUIPMENT CORP.

Anthracite Institute Building
WILKES-BARRE, PENNA.

ANTHRAFILT — an Improved Filter Medium

Trade Mark Reg. U. S. Pat. Off.

Address sales and technical inquiries to

Palmer Filter Equipment Company, 822 E. 8th St., Erie, Penna.

Anthrafilt and Its Application

Anthrafilt is made from a **selected** Pennsylvania anthracite which has been cleaned so as to have a minimum ash. This cleaned anthracite is then screened and classified hydraulically to yield sizes suitable for filter purposes.

Anthrafilt is used as a mechanical aggregate in place of sand and gravel in all kinds of filters, i.e.

Rapid gravity filters	Slow filters
Swimming pool filters	Pressure filters
Hot process softening filters	Oil removal filters
Cold process softening filters	Alkali filters
Mechanical sewage filters	Acid filters
Revolving screen filters	Sewage sludge-beds
Portable filters	Household filters

The entire filter bed may be made up of Anthrafilt of various sizes or only the top layer may be of Anthrafilt over the usual bed of gravel.

Advantages of Anthrafilt

High Filtration Rate: Rates up to 200 mgad are obtainable with Anthrafilt without sacrifice of effluent quality. The accepted average rate with sand is 125 mgad.

Long Filter Runs: The larger, irregular Anthrafilt grains allow less clogging with algae or other fibrous substances. The angular grain surfaces provide greater entrapping areas for the removal of turbidity and bacteria. The differences in shape and specific gravity of the grains, by decreasing classification after back washing, allow the whole depth of the filter bed to be active in the filter operation.

Low Wash Water Costs: The long filter runs and consequent less frequent washing and the low degree of packing after back washing combine to cut the usual wash water requirements at least in half.

No Cementing with Lime, Manganese or Iron: Lime will coat on Anthrafilt but this coating readily flakes off without any cementing action if filters are properly operated. Manganese and iron salts precipitated on Anthrafilt by the lime treatment are easily removed by back washing.

High Degree of Expansion: 50% expansion is obtained with half the back wash velocity required for sand.

Coarse Sizes Can Be Used: The irregular shape and natural filtration characteristics permit the use of much larger sizes with equal results.

Gravel Beds Stay Flat: No ridging or mounding and less cracking and pulling away from side walls during operation.

Low First Cost: Lighter weight per unit volume balances the cost differential between Anthracite and sand and saves on freight and handling charges.

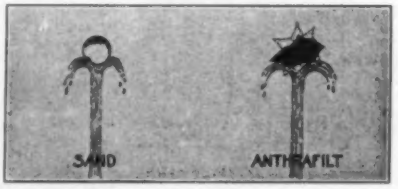
Filtration Characteristics

Anthracite granules are irregular shaped and of varying densities. Weights run about 53 pounds per cubic foot as against 100 pounds for sand. The irregular shapes provide greater porosity resulting in more rapid filtration with no loss in character of effluent and with considerably less loss of head.

The variable densities of Anthrafilt particles cause less classification after back washing and the lighter, irregular shapes allow easier expansion and more effective cleaning.

The greater bulk of Anthrafilt requires less tonnage per filter bed. Attrition losses amount to less than 0.25% per year.

Anthrafilt successfully removes lime, iron and manganese salts and will not form a permanent coating under proper conditions of treatment and filter operation. Lime flakes off easily without cementing and the iron and manganese salts are readily removed by back washing. Oil is easily removed from boiler water after coagulation with ferric sulphate, ferrous sulphate or alum. Anthrafilt can also be used for the filtration of acetic and sulphuric acids and caustic soda solutions. Being insoluble in alkaline waters, Anthrafilt produces silica-free water in hot process water softening.



Upward impulses of water produces greater agitation of angular grains, hence Anthrafilt beds are cleaned more effectively.

Anthrafilt No. 1 is usually made in sizes ranging from effective size of .60 m.m. to .80 m.m. the uniformity coefficient is less than 1.75 in all sises. We can make smaller sizes or larger sizes, but for special cases only. The remaining sizes of Anthrafilt are as follows:

No. 2. Anthrafilt—3/32"x3/16"
No. 3. Anthrafilt—3/16"x5/16"
No. 4. Anthrafilt—5/16"x9/16"
No. 5. Anthrafilt—9/16"x13/16"
No. 6. Anthrafilt—13/16"x1-5/8"
No. 7. Anthrafilt—1-5/8"x2-7/16"
The above sizes have 20% tolerance.

ANTHRAFILT ECONOMY

When Used in Existing Filtration Plants

Increased capacity with same plant
Decreased volume of wash water
Lower maintenance cost through elimination of ridging mounding and air binding.

When Used in New Filtration Plants

Lower plant investment
Lower cost per cubic yard
Lower wash water costs
Lower maintenance costs

RAPID SAND FILTER DESIGN AND MAINTENANCE*

A. H. ULLRICH
Superintendent
Water and Sewage Treatment, Austin, Tex.

VIEWED from a purely elemental standpoint, the essential parts of any rapid sand filter plant are as follows:

1. Filter box
2. Underdrain system
3. Filter media
4. Wash water troughs and gullets
5. Pipe gallery, consisting of
   a. Influent valve and piping
   b. Effluent valve and piping
   c. Waste valve and piping
   d. Wash water valve and piping
   e. Rewash valve and piping
   f. Rate of flow controller
   g. Rate of flow gage mechanism
   h. Loss of head gage mechanism
6. Wash water tank or pump
7. Wash water rate controller
8. Surface washing system
9. Clear-well

The detailed design of each component part as listed above, as well as the detailed design of the plant as a whole will depend on the total filtering capacity desired, on the type water to be treated, on the type treatment the water is to receive prior to filtration, and to other local considerations. The basic principles governing detailed designs are pretty well established, and it is, of course, the design engineer's responsibility to meet the local needs. While it is not in the province of this paper to discuss detailed designs, the writer would like to offer a few observations which, in his opinion, have a direct bearing on the maintenance and operation of the plant. It is freely admitted that some of the observations on design which follow may contain a few personal beliefs and prejudices. They are given, however, in the hope that an instructive open discussion may follow.

*A paper read before the Texas Water & Sewage Works Short School.

Filter Boxes

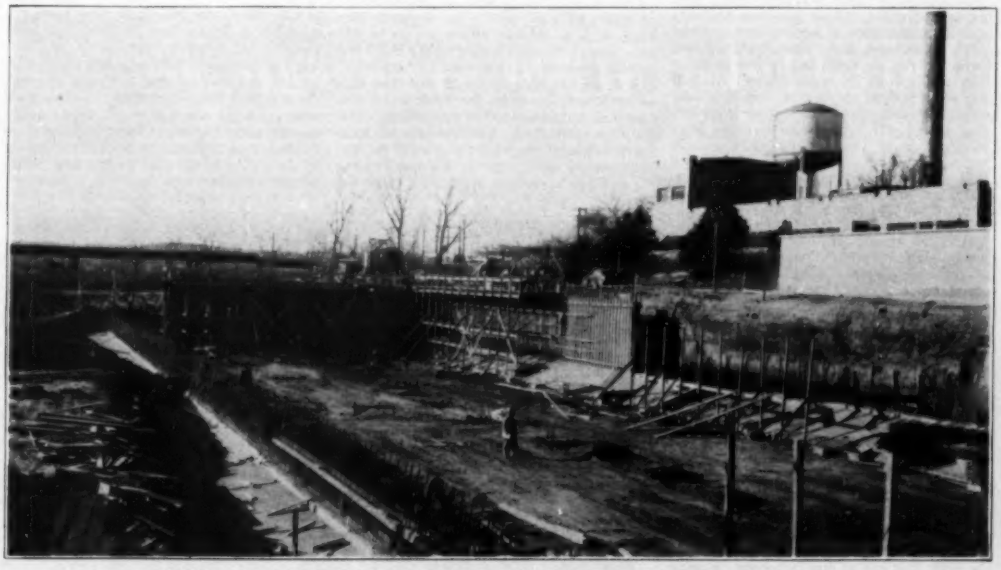
The maximum filtering capacity to be provided will, of course, determine the total cross-sectional area which the filters must have. If we assume a standard filtering rate of two gallons per square foot of filter area per minute and must provide a given number of gallons of filtered water per minute, then it is a simple matter to arrive at the required total filter area. The important decision which the design engineer must make is into how many units to divide the required area. His decision should be based on a balance of economy of design as against flexibility of operation. The writer believes that even the smallest plants should have at least two filter units, so that one unit may be taken out of service for repairs while the other unit is still in operation. In designing filters for larger plants, the design engineer must balance the cost of not only the filter boxes but also the cost of the control valves and piping, rate of flow controllers, wash water facilities and other appurtenances, against flexibility of operation. Another factor to consider is that if the plant is ever expected to expand, any additional units that are added will almost of necessity be of the same size as the original units unless separate wash water and waste facilities are provided.

Incidentally, in recent years some of us have had to exceed by a material margin the former standard filtering rate of two gallons per square foot of filter area per minute. While this higher rate has proven to be safe practice where we have maintained an applied water of good quality and have maintained our filter beds in good condition, it is our opinion that the two gallon rate is still sound practice in new plant design. This conservative design will provide an added factor of safety should the plant be required to take on an increased load before it can be expanded. Such has been well proven during both World Wars, particularly during World War II.

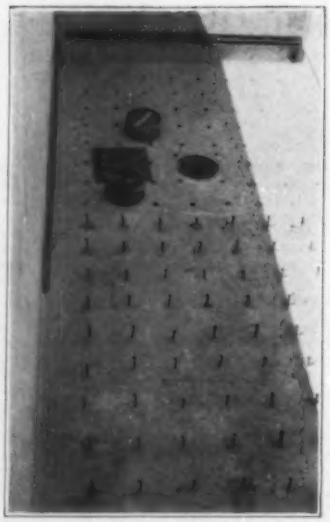
Filter Underdrain System

Some time ago a representative of a filter equipment manufacturer informed us that his firm had devised the perfect underdrain system. Perhaps we operators are looking for the impossible, but it is nice to dream of perfect underdrain systems. However, we doubt that any truly perfect has been built as of the present writing.

In Austin we now have in use three different types of underdrain systems; namely, Infilco's Wagner Blocks, Builder's manifold and lateral system using coarse media between the laterals, and Carborundum Co.'s "Aloxite" brand porous plates. Since Austin has practiced lime softening without recarbonation for over twenty years, and is still using this method of treatment, there is considerable incrustation of the filter media as well as the underdrain system. This probably requires us to carry on a more extensive filter maintenance program than would otherwise be required. But such



Addition of a 3,000,000 Gal. Clear-Well to the 800,000 Gal. Clear-Well at the Austin Plant.
An important addition to increase flexibility of plant operation and smooth out load fluctuations on the filters and chemical treatment facilities.



Bottom of Filter Box—First Stage
Before pouring piers to support porous filter bottom plates. Note supporting angle iron around walls.

maintenance work has other distinct advantages, and, in addition, gives us a pretty good opportunity for studying different types of filter construction. In our plant we have had very good service from both the Wagner Block type underdrain and Builder's conventional manifold and lateral system. The chief objection to both of these types of underdrain is that various sizes of coarse media are still required to support the fine material, and the coarse particles have a habit of getting mixed with the fine particles. All of you have probably had the experience of having fine material work down into the coarse material and have, no doubt, even had it work down into the laterals of some filters. Also, if any work is done on the filter bed, it is very difficult to keep the various sizes from getting mixed. If for any reason the filter media must be removed for work on the underdrain system, then it must be regraded before it can be returned to the filter box. This, as you who have experience know, is a tedious and expensive job.

The porous plate type underdrain eliminates the mixing of the various sizes of media since only the fine grade of media is required. Such a filter bed will withstand more abuse from air binding, and resulting explosive wash, and excessive filter runs, without permanent damage to the bed. Also, if it is desired to clean the filter bed, it can be vigorously agitated with water or air or both, or it can be shoveled back and forth in the filter box. Before becoming associated with the Austin plant, the writer had excellent results from the use of porous bottom plates at Fort Smith, Arkansas, where a soft mountain lake water was coagulated, settled, and filtered. The Austin plant had two porous plate bottom filters when the writer became associated with it something over a year ago, and we installed three additional porous plate filters in 1948. Because of the carbonate incrustation obtained with our present method of treating, it appears likely that we will be required to clean the plates with muriatic acid at some as yet undetermined intervals. We cleaned the plates in the two original porous plate filters with muriatic acid last spring, merely as a safety factor for last summer's load. These are outside filters and were not originally equipped with loss of head and rate of flow gages. Since we are just now getting them so equipped, we have not been able to record any material increase in the loss of head through the plates. At the present time it appears that carbonate incrustation will *not* be a serious problem, because our experience last year demonstrated the ease with which the plates can be uncovered, treated with muriatic acid, washed, and the filter returned to service. The cleaning procedure was to shovel all the filter media from one end of the filter to the other, treat the exposed plates, wash the filter, and repeat the procedure for the other end.

Filter Media

While the title of this paper is "Rapid Sand Filter Design and Maintenance," a more appropriate title would probably be "The Design and Maintenance of Rapid Filters." As all of you know, many plants now use "Anthrafilt" instead of sand for the fine media; and, many plants also use coarse anthrafilt instead of gravel for the coarse supporting material. "Anthrafilt" is, of course, the trade name of the filter media prepared from crushed and graded anthracite coal. Opinions are still divided as to the relative merits of sand and "Anthrafilt," probably because each seems to have a definite field in which it excels. The writer has had excellent results using sand with an effective size of approximately 0.45 mm. in filtering soft, coagulated, and settled water where the chief problem was removal of colloidal clay and color. It is doubtful that the standard "Anthrafilt" which has an effective size of 0.60-0.80 mm. would have given equally good results. In the Austin plant, we are using standard "Anthrafilt" for filtering lime softened and settled water and are obtaining good results. The material which we are using has an effective size of 0.60-0.80 mm., and it is probable that sand with a similar effective size would also give good results. One of the chief and valid arguments for the use of "Anthrafilt" is that its specific gravity is less than that of sand and, therefore, the wash water rise required for adequate bed expansion is less for "Anthrafilt." In Austin where we have incrustation of the media particles, the importance of this factor is reduced because the calcium carbonate film which forms on the surface of each particle increases the specific gravity of the "Anthrafilt" particle. We have found that in some of our older filter beds the fine "Anthrafilt" carried a coating of calcium carbonate which was as high as 75% of the total weight of the media, but was still doing a good job.

The writer's experience, so far, indicates that when using sand an effective size of from 0.40 mm. to 0.50 mm. probably makes the best filter media for use with soft water which is difficult to coagulate and settle. Highly turbid waters and waters containing colloidal clay and color probably come in this category also. On the other hand, the larger "Anthrafilt" seems to have an advantage where lime softened water or water which is easily coagulated and settled is to be filtered.

Air Binding and Bed Cracking

The type of water which results from the preparation given it ahead of the filters will determine the best methods of operation and maintenance to employ in keeping our filter beds in first class condition. Soft waters, high in colloidal clay, color, or algae concentrations, are sometimes difficult to coagulate and settle, and the resulting excessive floc carry over may cause rapid filter clogging. If filters are permitted to become too dirty, the fine media will probably develop cracks and will likely pull away from the filter box walls. This will permit floc to penetrate the beds so deeply that it will become difficult to wash the filters clean. Also, if the surfaces of the beds become badly clogged, the filters will often become air bound. When a filter with a tightly packed surface layer and air in the underdrain and lower layers is washed, there is excellent opportunity for disrupting the entire bed, resulting in mixing the sand and gravel or the coarse "Anthrafilt" with the fine. The writer believes that, if at all possible, filters should always be washed before there is any appreciable amount of air binding. If air binding does begin to show up in the filters, then it is good practice to reduce the length of filter runs and establish a lower loss of head for filter washing. If there is appreciable air binding, the filter should be removed from service and the air permitted to escape as much as possible before turning in the wash water. If the air will not escape rapidly enough after the water level is lowered on the bed, then it should be worked out slowly by just "cracking" the wash water valve before washing.

Bottom of Filter Box—Third Stage
Completed concrete piers ready for placement of porous bottom plates.

Bottom of Filter Box—Second Stage Forms in place for pouring concrete piers.

Length of Filter Runs

In lime softening plants, and in other plants where a very clear applied water is often obtainable, it may be possible to keep filters in operation for long periods between washings without air binding, without appreciable loss of head build-up, and without a drop in the rate of flow. How long a filter should be operated thus, with a clear applied water, will depend on local conditions. In Austin, where we filter an incrusting water, we now feel that excessively long filter runs cause binding and lumping of the filter media. In other words, we believe that if the filter bed is not agitated and washed often enough, the sand or "Anthrafilt" particles will become cemented together by the incrusting material so that washing will not completely break them apart. We have not yet arrived at what we believe the maximum filter run should be in our case, but it now appears that it will not be in excess of 72 hours. We have three new filters which will be used for the first time this year, and we plan to place each on a different maximum run schedule to try to determine the maximum safe run.

The length of filter runs to be used at a given plant involves the type and quality of applied water which can be obtained at the plant. Obviously, the filter runs should also vary with variations in the quality of the applied water as well as with variations in the filtering rate. Filter wash water costs money; and, good practice dictates that we make our filter runs as long as possible without endangering the quality of our effluent or cause damage to our filter beds. In this connection, we should remember that filters are installed for the purpose of removing impurities which are not removed by prior treatment. If excessive filter runs tend to defeat this purpose, either because of damage to the beds or because of deterioration of accumulated organic matter, then we need to shorten our runs. Likewise, if our filter beds have been in service so long that they will no longer function satisfactorily, then they should be replaced with new material.

Wash Water Troughs and Gullets

The design of wash water troughs and gullets has become so well standardized that they are mentioned here only in passing as being necessary parts of a filter. However, there is reason to believe that study might be given to the arrangement of the troughs, looking toward improved filter washing.

Pipe Gallery

In designing a filter pipe gallery, special care should be exercised by the design engineer to provide ample room for ready access to all valves, rate controllers, loss of head and rate of flow gages, so that they may be easily inspected, maintained, and repaired. The installation of filter control valves should be made under careful inspection, as the writer has known of horizontal valves being installed upside down and vertical valves with downstream guides being installed backwards.

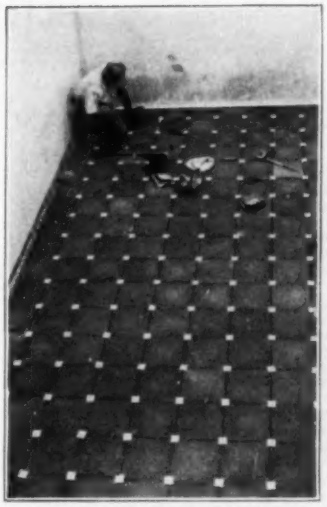
The writer believes it to be good practice to provide adequate lighting in the pipe gallery—even to painting the walls and ceiling white—in order to encourage good maintenance of the control valves, controllers, gages, and other equipment. Where hydraulic filter control valves are used, care should be exercised in selecting the best possible packing. It is difficult to stop leakage with poor packing, and there is danger of scarring the valve stems and of causing sluggish valve operation if the packing is too tight.

Wash Water Tank or Pump

The design engineer must exercise his judgment as to whether to provide a wash water tank or a pump. The writer has always been prejudiced in favor of a tank, but he realizes that a properly designed pump can do an adequate job. Backwashing with water from a force main through pressure reducing valve has usually not been successful, even in small plants. Where wash water tanks are provided, it is usually good economy to install a low head pump for pumping water into the tank and also to provide a standby connection from a force main for use in case of pump failure.

Wash Water Rate Controller

Wash water rate controllers are helpful in assuring a uniform washing rate. If properly adjusted and in good working order, they are a good protection to the filter bed.



Bottom of Filter Box—Final Stage Completing the porous bottom by bolting down the plates and pointing up spaces between plate edges.

Surface Washing System

Perhaps one of the best investments that a filter plant can make for protection of the filter bed is the installation of a well-designed surface washing system in each filter. The writer knows of no better method for keeping filter beds clean and for eliminating mud ball formation than the proper use of a good surface washing system. Either the patented Palmer "Filter Sweep" or the Baylis stationary type surface wash system will give good results.

Clear Well

Aside from meeting Fire Underwriters' requirements in filtered water storage capacity, the clear well capacity should be sufficient to give maximum flexibility to the plant. From a plant operation standpoint the ideal clear well should be large enough to permit the entire plant to operate at a fairly uniform rate during each twenty-four hour period. The nearer this ideal is approached, the nearer will the entire plant be in position to operate at maximum capacity. It is because of this that the Austin clear well is being substantially enlarged at this writing.

FILTER SAND SPECIFICATIONS*

THOMAS M. RIDDICK

Consulting Engineer and Chemist, New York

The original work on filter sand was done by the late Allen Hazen about 1890. Hazen introduced the terms "effective size" and "uniformity coefficient" which are in use today. As Baylis has pointed out, however, Hazen's work was primarily applicable to "slow" rather than to "rapid" sand filters.

Sand employed in the former was often unwashed and ungraded and hence contained a relatively high per cent of "fines" and the sizes extended over a wide range. It was not uncommon to have an effective size as low as 0.2 mm. with a uniformity coefficient of 3.0 or higher.

With these conditions, Hazen found that the fine sand (0 to 10 per cent) had about as much effect upon filtration efficiency as practically all the other sizes combined.

Today, the "fines" (retained on 150, 100 and 65 mesh), as well as the coarse sand (retained on 12 and 14 mesh screens) are eliminated by the producer through washing and screening. Under these circumstances, effective size and uniformity coefficient lose much of their original significance.

There are two screen scales available. The clear opening between meshes of the "square root of 2 series" increases in the ratio of 1.414. This is entirely adequate for filter sand analysis. The greater refinement enabled by the "fourth root of 2 series" (1.189) is not warranted.

According to the theory of hydraulic subsidence, backwashing *should* grade sands within a layer, leaving the coarsest material at the bottom and the finest at the top.

Filter Sand Requirements

A filter sand should be used which will produce a clear and sparkling effluent—free from coagulant—under the *worst* rather than *average* conditions of floc formation. The poorest coagulation is generally experienced during the fall season.

Filter sand should also *completely* prevent the passage of activated carbon when this is applied to the top of the layer. This important qualification has arisen only within the past several years.

Effect of Fine Sand on Clarity of Effluent

Repeated instances have shown that when 35 (and some 48) mesh sand was added to either pressure or gravity filters deficient in these sizes, immediate improvement in the clarity of the effluent was noted. This led to the author's firm conviction that fine sand is essential to the production of a finished water with a turbidity comparable to distilled water.

Although fine sand will undoubtedly give a shorter filter run than coarse, this is partly due to the removal of a greater per cent of suspended matter from the treated water. Long filter runs are more dependent upon the design and efficiency of the mixing basin and the retention period of the sedimentation basin than upon the size of sand employed.

The loss of head through either fine or coarse sand takes place principally at the surface as is shown by the complete recovery of a slow sand filter after skimming.

From both theoretical and practical considerations, all 65 mesh sand should be excluded, or, in other words, the "finest" sand which can be maintained in a layer at 50 per cent expansion is the 48 mesh size.

Stratification of Filter Sand

Table I gives the results of analyses of samples collected at the Danbury, Conn., plant. The amount of sand retained on the 65 and 14 mesh sieves was less than 1 per cent, which, for practical purposes, may be disregarded. The significant amounts in all filter sand analyses are those retained on the four sieves: 20, 28, 35 and 48 mesh.

This table lists seven individual analyses, each showing "per cent retained" and "per cent passing." From the latter values have been computed the "effective size" and "uniformity coefficient" found in each stratum.

The top ½ in. layer of sand contained approximately 80 per cent of 48 mesh and 20 per cent of 35 mesh sand. The effective size for this stratum was 0.35 mm. and the uniformity coefficient 1.17. Most of the stratification took place within the top 2 in., although a definite gradation in both 48 and 28 mesh sizes is also seen from top to bottom. This filter showed the best hydraulic grading of those sampled, though mud balls were present at all depths. The author considers this an ideal grading, and the presence of the large per cent of 48 mesh on top of the filter gives excellent reduction in turbidity.

The results of Mamaroneck, N. Y., samplings show this sand had an effective size of 0.45 mm. and a uniformity coefficient of 1.32, and is well adapted to good filtration. Practically all stratification took place within the top 2 in., which is the region mainly responsible for the removal of floc and turbidity. The per cent of 48 and 20 mesh was small, and the sand was roughly two-thirds 35 mesh and one-third 28 mesh.

At Nyack, N. Y., the per cent of 48 mesh was low, but the bulk of this was found in the top 2 in. and practically all in the top 6 in. The stratification of the 35 mesh is evident only in the top 2 in. A small per cent of 20 and 14 mesh sands were present and these were uniformly distributed from 2 in. below the top to the bottom. This demonstrates in general the advisability of excluding if possible the 14 and perhaps 20 mesh sand entirely. The effective size of the entire layer was 0.50 mm. and the uniformity coefficient 1.38. Since the placement of this combination of sand sizes, the filter has consistently produced an effluent with turbidity quite comparable to distilled water and has not permitted the passage of any carbon applied to the top of the filter, when applied one-half hour after backwashing.

At Ossining, N. Y., little stratification was evident. The proportion of 20 mesh sand (which was low in the previous filters) was relatively high in this filter. Two inches of fine sand (35 and 48 mesh) were added and resulted in a lowering of

ON PAGE 218 of the July, 1945, issue of *Water Works & Sewerage* there appeared an article on Filter Sand Grading. Written by J. Tarrant of Ruislip, England, the article contained a nomograph relating uniformity coefficient, effective size and mesh size.

Following the publication of this article, Cecil Calvert, Supt. of Filtration, Indianapolis Water Co., wrote to say that his company had used the specifications proposed by the author in 1939 and had found them completely satisfactory. In view of this comment, the editors of *Water & Sewage Works* asked the author to abstract his original article (*JAWWA* 32, 121, 1940) for use as Reference and Data material.

The original article was developed from a study of filter sand, filter sand classification, effect of wash water rise, and location of wash water troughs at six filter plants, as well as the theory of filter bed expansion, and sand specifications.

For the present purpose, it is only necessary to abstract the information and data on sand classification together with the filter sand specifications the author proposed at that time, as a result of those studies.

TABLE I

Analyses of Sand Filter No. 5, West Lake Plant, Danbury, Conn., August 11, 1939

Sieve Number	Depth in Layer 0"-½" Per cent Ret	Pass	½"-2" Per cent Ret	Pass	2"-6" Per cent Ret	Pass	6"-12" Per cent Ret	Pass	12"-18" Per cent Ret	Pass	18"-24" Per cent Ret	Pass	24"-28" Per cent Ret	Pass	Total —Per cent— Grams	Ret	Pass
65	1.8	...	1.0	...	2.1	...	0.7	...	0.4	...	0.1	...	0.6	...	6.7	0.9	...
48	80.2	1.8	62.1	1.0	39.1	2.1	20.3	0.7	16.3	0.4	11.9	0.1	9.2	0.6	239.1	34.2	0.9
35	18.0	82.0	36.9	63.1	55.7	41.2	60.2	21.0	61.3	16.7	59.6	12.0	49.0	9.8	340.7	48.7	35.1
28	...	100.0	...	100.0	3.1	96.9	16.3	81.2	19.3	78.0	25.4	71.6	26.1	58.8	90.2	12.9	83.8
20	...	...	...	...	...	100.0	2.5	97.5	2.7	97.3	3.0	97.0	6.2	84.9	13.4	1.9	96.7
14	...	...	...	...	...	...	...	100.0	...	100.0	...	100.0	3.7	90.1	3.7	0.5	98.6
8	...	...	...	...	...	...	...	...	...	...	...	...	6.2	93.8	6.2	0.9	99.1
														100.0	700.0		100.0
Effective Size—mm.	0.35		0.36		0.36		0.39		0.40		0.42		0.42				0.38
Uniformity Coefficient	1.17		1.17		1.36		1.41		1.41		1.39		1.45				1.40

*An abstract of an article on "Filter Sand" which appeared in the January issue of the *Jour. AWWA*, p. 121, 1940.

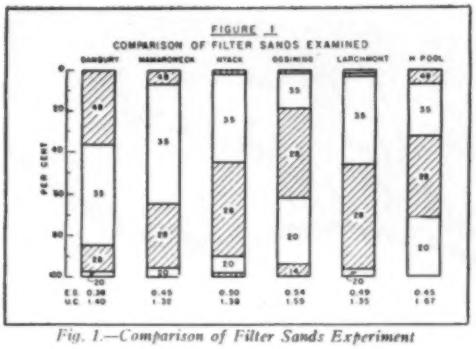


Fig. 1.—Comparison of Filter Sands Experiment

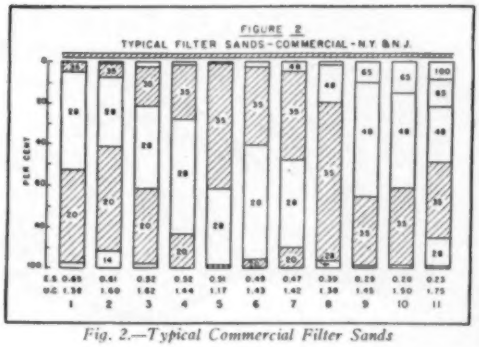


Fig. 2.—Typical Commercial Filter Sands

turbidity of the effluent from 0.4—0.5 to 0.0—0.2 ppm.

At Larchmont, N. Y., the hydraulic grading was very good, but contrary to the preceding findings, the coarsest sand (28 and 20 mesh) was found at the top, and the finest sand (35 mesh) was predominant at the bottom of the layer. This sand was jet black and coated with 12 per cent of manganese oxide, computed as Mn. The specific gravity was determined for the 35 and 28 mesh sands respectively, and it was found that the larger sizes were lower in weight per unit volume than the smaller sizes due to the build-up of the porous coating. The effect of density was sufficient to cause complete reversal of normal hydraulic subsidence, but this is in accordance with Stokes' law, which states that the rate of subsidence is proportional to the square of the diameter and to the difference between the specific gravity of sand and water. This filter, however, functions as a contact layer for removal of manganese as well as for filtration.

The Highbridge Pool filter was sampled since the lip of the wash water trough is 54 in. above the top of the sand, which is approximately twice the conventional distance. Here we note a relatively large per cent of 20 mesh and a reduction in the 35 and 48 mesh sizes. This naturally greatly increases the uniformity coefficient. No stratification existed below the 2-in. depth.

Comparison of Filter Sands Studied

Fig. 1 shows a comparison of all filter sands examined. Effective sizes ranged from 0.38 to 0.54 and uniformity coefficients from 1.32 to 1.67. The Danbury filter, with low effective size and uniformity coefficient, showed the best stratification. The stratification at Nyack was better than at Ossining, which may be due to the use of three sizes of sand at the Ossining plant as compared with practically two sizes at Nyack.

Comparison of Commercial Filter Sands

Fig. 2 gives typical commercial filter sands produced in New York and New Jersey. Numbers 1 and 2 would give the longest filter runs. Due to the large amount of 20 mesh and the inclusion of some 14 mesh, No. 2 would probably require less backwashing. The amount of 35 mesh sand present, however, is too low to provide efficient filtration during times of poor floc formation. The characteristics of these sands are more similar than is indicated by the existing variation between effective sizes and uniformity coefficients.

Number 3 has a larger per cent of 35 mesh, but too great a per cent of 20 mesh. Number 4 is a fair filter sand, although it would be preferable if the 35 mesh were increased, and the 20 mesh decreased.

Numbers 5, 6, 7 and 8 are the best of the lot, and No. 8 would undoubtedly give the clearest effluent, but shortest filter run. It is adapted to a plant with a sedimentation period of 4 to 6 hours. Number 6, with a uniformity coefficient of 1.43 and an effective size of 0.49 mm., would be best for a 3-hour basin. The small amount of 48 mesh sand would be found largely at the top of the layer.

Numbers 9 and 10 are useful for addition to an existing filter which is lacking in "fines." Number 9 could be added to No. 1 to very good advantage, and would result in a marked improvement of this sand. Number 11 is worthless for filters since it contains too much 100 and 65 mesh. It would increase the uniformity coefficient when added to practically any sand, and at least 22 per cent (representing the 100 and 65 sizes) would soon be lost through backwashing.

Selection of Filter Sand

The bulk of so-called filter sands on the market today are in reality screened for moulding and blasting. The demand for filter sand is exceedingly low and amounts to only two-tenths of 1 per cent of the total sand sold commercially, excluding that used for building, paving and railroad ballast.

In selecting a filter sand it is preferable to take a standard grading rather than have a producer change his screens to meet rigid specifications. The output of several companies should be examined. If necessary, two sands may be blended when the filter is built. If this is done by the producer, the shipment may materially differ from the sample submitted.

In the opinion of the writer, the 48 and 20 mesh sizes should be limited to about 10 per cent each, with the latter excluded if possible. The 35 and 28 mesh sizes should be present in about equal proportions. If a long sedimentation period is provided, the 48 mesh sand may be increased slightly. Sands of this type will have an effective size of about 0.50 mm.; a uniformity coefficient of less than 1.45.

The specifications with regard to sizes suggested by the author are given in Table II.

The selection of torpedo sand is very important since 35 mesh sand is present next to this fine gravel. If it is too coarse it would seem to provide a ready passage of the 35 mesh material down into the underdrains. On the other hand, it should not be so fine as to be lifted during backwashing. The writer believes that torpedo sand should pass a No. 6, and about 50 per cent each should be retained on No. 8 and No. 10 mesh screens (14 and 20 mesh sand will not remain in place).

In this instance, the maximum diameter of particle is 3.33; minimum, 1.65; and average, 2.5 mm. The average size of 35 mesh sand is 0.50 mm. The average diameter of torpedo sand is 5 times the diameter of the 35 mesh. From a theoretical standpoint, the maximum ratio to prevent passage of fine sand is 6.4. It would seem desirable therefore to limit the 48 mesh sand to that quantity which will remain in the top 6 in. of the filter.

TABLE II

Suggested Size Specifications

Sieve Number		Sieve Opening	Per Cent Retained on Sieve	
√2 Series Tyler Standard	U. S. Series Equivalent	Millimeters	Minimum	Maximum
65	70	0.208	0	1
48	50	0.295	0	9
35	40	0.417	40	60
28	30	0.589	40	60
20	20	0.833	0	9
14	16	1.168	0	1

Conclusions

1. The finest size of sand that should be used in a rapid sand filter employing 50 per cent expansion is that retained on a 48 mesh sieve.

2. Thirty-five mesh sand (*average* size 0.50 mm.) is required for low turbidity of effluent and to prevent the passage of activated carbon.

3. In specifying filter sand, it is preferable to use "per cent retained on" rather than "effective size" or "uniformity coefficient."

4. The 48 and 20 mesh sizes should be limited to not more than 10 per cent each, with the latter omitted if possible. The predominant sizes should be 35 and 28 mesh, and these should be present in approximately equal amounts.

5. Torpedo sand or fine gravel should be carefully selected as to size.

Attention— All gravity filter Plant Engineers!

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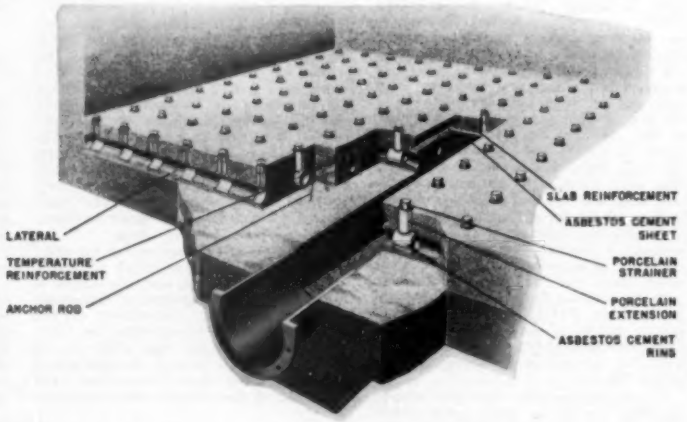

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- All parts of the underdrain are non-corrodible.
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- Strainers are uniformly spaced regardless of filter dimensions.
- Inexpensive and easily constructed.
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The Permutit Monocrete Underdrain is of monolithic construction, the header and laterals consisting of conduits cast in concrete. Porcelain extension stems extend from the header and laterals to the top surface of the concrete; heavy porcelain strainers are screwed into these stems. The laterals are formed by specially designed inflatable rubber tubes which are removed after the concrete has set. The top slab of the header is then poured, using asbestos-cement sheet forms which are left in place.

For full information about this remarkable new unit, write to The Permutit Company, Dept. W-5, 330 West 42nd St., New York 18, N. Y., or to the Permutit Company of Canada, Ltd., Montreal.

Permutit

WATER CONDITIONING HEADQUARTERS FOR 37 YEARS

SMALL WATER TREATMENT PLANTS*

Comments on Design Features, Operating and Personnel Problems

THOMAS R. LATHROP
Prin. Asst. Engineer
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TO a great extent, the problems of the small and large treatment plant are similar. The raw waters of both produce the same problems of purification, including chemical application, filtration and disinfection. The differences in operation are the result of differences in plant design and also in the type of personnel usually employed.

A plant with a capacity of 0.5 mgd. or less is considered a small plant. The plant operator usually is responsible for the entire system, from operating low-service pumps to reading the meters and sending out the bills. This discussion, then, will be confined to plants of 0.5 mgd. or less. Even in this category, many plants are provided with the same features as larger ones, and treat waters presenting similar problems of turbidity, tastes, odors, hardness and bacterial contamination. Some small plants also have well-trained operators. But differences in design, operating conditions and personnel problems do occur.

All water treatment plants constructed in Ohio must have the approval of the Ohio Dept. of Health. A few of the regulations governing these plants are: (1) The rate of filtration required is 2 gpm. per square foot in purification plants using surface waters. In the case of softening and iron removal plants, using ground waters, a 3 gpm. rate is permitted. (2) Filter rate controllers are required on all filters. (3) Open gravity filters are required for all surface waters, but pressure filters are permitted in softening plants which treat ground waters. (4) Settling basins having at least four hours' detention are required at all plants using surface waters, although for ground waters which are softened shorter detention periods are allowed.

Design Features

The construction of completely new water works including treatment plants so taxed some of the small municipalities that the water works structure was not made large enough to provide space for chemical storage. The filters reach almost to the roof, making it very difficult to get into a filter and even more difficult to remove and replace the sand and gravel. At some plants of this sort a small building adjacent to the filter building is used for storing chemicals. Such arrangements add to the problems of operation, however.

Reaction and Settling Units

Cylindrical steel reaction and settling tanks, which are often employed for economy's sake, usually afford rather inefficient mixing. In some plants where the lack of effective mixing has been noted, the addition of mechanical mixing devices has improved conditions. When lime-soda softening is involved, the steel tank serves as a mixing chamber, settling basin and recarbonation basin, with recarbonation occurring in the out-take pipe. The water is generally not stable when it reaches the filter, and the sand encrusts rapidly.

Filter Washing

Surface washing not only keeps the sand in filters in clean condition, but in the softening plant it reduces the rate of incrustation of the sand. In the small plant, surface washing can be provided from piping which is usually on hand. A small grid of 1-in. pipe placed in such a filter makes an excellent surface washer. It is simple to construct and is so small that it can be easily handled if it becomes necessary to remove it from the filter.

Chemical Feeding

Chemical application for the small plant is best provided by using solution feeding devices. Few of the dry feeders will apply chemicals accurately in the small amounts usually required. Too often the chemical storage space is in the same room as the filters and pipe gallery, where moisture conditions affect the chemicals—especially lime and soda-ash—so that they cannot be fed accurately by any volumetric dry feeder. Incidentally, accuracy of chemical application is more important in the small plant than in the large one. Over- and undertreated waters are much more apt to reach consumers in small communities. In spite of this, many small plants continue to be equipped with dry feeders which give no end of trouble.

Recarbonation

The recarbonation of lime-softened water presents many problems in all plants, and the small plant is no exception. When natural gas is available, a gas burner is usually employed for producing carbon dioxide. Kerosene burners are generally more satisfactory in the small plant than coke burning furnaces, because operation is usually intermittent and a small coke fire is difficult to keep burning. Recarbonation units employing dry ice (solid CO_2) are of great advantage, although the cost is perhaps somewhat more than for carbon dioxide generated as a product of combustion. There is no problem of generation or compression; the dry ice is delivered in sizable blocks which are cracked up and placed in a screw-capped pressure cylinder. The gas coming from the top of the cylinder is measured by a rotameter and diffused through a submerged fabric hose of the type used for watering lawns or gardens and sold under the name "Soil Soaker." Excellent results are reported.

In some small lime softening plants, recarbonation is not practiced because of the difficulties involved. Vitreous phosphate[1] known as "Calgon" is applied in an effort to offset the effects of water saturated or super-saturated with calcium carbonate. This treatment prevents the incrustation of the filter sand, pipelines, meters, etc.—but, if water is treated with excess lime, the vitreous phosphate does not remove the causticity and a caustic taste often remains.

Filters

Pressure filters are installed as an economy measure at certain small water treatment plants. In Ohio, the installation of pressure filters is discouraged and such units are permitted only at plants designed for ground water softening or iron removal. Very little need be said about the disadvantages of this type of equipment. Tastes and odors at times develop in these units as a result of biological growths. The sand cements together, and overhauling such filters is a disagreeable job.

Gravity filters are occasionally constructed using steel shells, some as small as 5 or 6 ft. in diameter. Concrete units providing 25 sq. ft. of filter area are about the smallest size that should be constructed. Smaller units are too difficult to work in during construction and overhauling operations.

Rate Control

Rate controllers are most economically constructed for one or two filters by employing a float chamber which provides a constant head over an orifice. The only problem of operation is to keep the float valve working freely. Putting a proper cover over these controllers is quite important if foreign matter is to be kept from the clear well. The type of rate controller usually supplied employs a hydraulic valve actuated by pressure on a diaphragm and is very satisfactory in the plain filtration plant. It is of little use in many lime-soda softening plants because the pilot becomes encrusted and the controller fails to function. If vitreous phosphate is introduced into the water ahead of the filters, this trouble is eliminated. However, a water harder by 20 ppm. be expected when this chemical is applied to the water before filtration.

Pumps

Pumps in the softening plant using pressure filters usually take suction from the settling tank discharging through the filter into the distributing system. In softening plants this arrangement has the serious drawback of causing incrustation of the pump runner and housing, making it necessary to take the pump out of service about once or twice a month for removing calcium carbonate. This coating is very hard and crystalline in character. An acid bath is the most effective method of cleaning. To remedy the condition, the high-service pumps may be arranged to take suction from the filter effluent instead of the influent. When the water passes through the filter before it reaches the pump, it has become more stabilized and little further trouble is experienced with incrustation. Vitreous phosphate applied to the suction of the pump will also prevent incrustation of the pump by calcium carbonate.

Filter Washing

A wash water tank is usually lacking in the small plant. Sometimes a pump is provided, but very often the wash water is drawn from the main discharge of the plant to the distribution system. This is practical if there is an elevated tank on the system and if the filters require only a relatively small amount of wash water. At one plant, with a 6-in. force main

*This paper, presented before the Annual Meeting of the Am. Water Works Assn., is here published by the permission of the Association.

[1]Produced by Calgon, Inc., of Pittsburgh, Pa.

about two miles long, the single filter was divided into two parts for washing purposes, so that enough wash water would be available from the small force main with its high friction loss. It is desirable that an auxiliary gate valve regulating the rate of filter wash be placed on the main wash water line so that wash water valves on each filter can be opened wide without danger of upsetting the sand and gravel bed.

Automatic Controls

Clear wells have been omitted in some small plants in order to reduce the cost. Pumps take suction directly from the gravity filter effluent line and discharge into the distribution system. An elevated tank usually floats on the system, but sometimes a pump with automatic controls discharges into a hydropneumatic tank. The pump is in frequent operation during certain parts of the day. At some plants, the pumps will start as often as once a minute, operating for from 10 to 15 seconds at a time. Treating water under these conditions certainly presents problems which the large plant operator never encounters. Automatic equipment, actuating low-service pumps, chemical feeders, filters and the like, materially facilitates operation of a plant of this type.

Operating Problems

Raw waters from impounding reservoirs often contain algae. For the most part, the small plant operator does not determine what organisms are involved but employs copper sulfate in varying amounts at different locations. Usually the copper sulfate is applied on more or less of a schedule, such as once or twice a month. If the conditions are not improved, a supervising chemist may be called upon to advise a treatment.

The aeration of well waters is frequently accomplished adjacent to the filter building. Spray from the aerator saturates a brick building wall and the chemicals stored inside near the wall will take up so much moisture that it becomes impossible to feed them with a dry feeder. Separation of the aerator from the building is advisable.

Mixing devices at some softening plants require a great deal of maintenance because the small plants operate intermittently. Sludge collects on the bottom of the basin during the period of shutdown and makes it difficult to start the mechanism, with breakage often resulting.

The operation of filters in the plain filtration plant is largely a matter of keeping the filter material clean and free from mudballs. In the lime softening plant, the problem of maintaining filters is much more serious. The sand becomes heavily incrusted and at times cements together, forming large chunks and slabs. The operator must be continually on the watch to prevent this condition. The filters should be prodded with a long-handled rake each time they are washed, so that the operator may know the condition of the sand. As previously stated, a surface wash system will prove very helpful in preventing sand agglomeration. Frequent removal of sand from the surface of the filter is necessary to keep the sand level at a point below the bottom of the wash water troughs. When sand is heavily incrusted, little or no sand expansion takes place during the washing operation. The effective size of the surface sand often reaches 2 mm. or more. Below the surface the size is much smaller.

In washing purification plant filters, the operator must learn to work the wash water valve slowly. Valves in small plants are usually manually controlled and often cannot be opened too rapidly, but many are opened fast enough to upset the gravel layer. The carborundum-plate filter bottom which is coming into use should prevent troubles resulting from displaced gravel layers.

Tastes and odors are attacked in the small plant in about the same manner as in the large one. The operator of a small plant does not have the facilities for making threshold odor tests. And he may not have the training to test for *free residual* chlorine. Activated carbon and combined chlorine are usually employed for taste and odor control. *Free residual* chlorination is used for taste removal at a few small plants where the operator is competent to control it.

Disinfection at the small plant is usually best accomplished with hypochlorite rather than with liquid chlorine, because the use of hypochlorite is, overall, more economical as well as being more simple in operation.

The maintenance of the plant in a neat condition is more of a small than a large plant problem, as the small plant often has no space for storage and becomes cluttered up with all sorts of equipment. In building small water works plants provision must be made for chemical storage, tool and meter room, and general storage space if anything approaching neatness is to be attained by the operator.

A small amount of effort toward landscaping the works will greatly improve its appearance. The planting of trees and shrubs can be done with no outlay of money because individual citizens or the garden club can be depended on for material if the water works man indicates an interest.

Personnel Problems

In the small plant the water works income is often so restricted that the salary which can be paid to the operator is insufficient for full-time employment at the water treatment plant. Usually, in addition to operating the purification plant, he looks after the pumps and the distribution system, makes taps, reads the meters, sends out the bills and collects the revenue. He frequently ekes out a living by acting as town marshal, driving the school bus, running a motion picture theater or acting as janitor of the school. Such versatile men are operating some of the small plants.

These operators, who make regular daily coliform, alkalinity, pH and hardness tests, generally had no formal education beyond high school. Many have had none beyond the eighth grade. They have acquired their technical knowledge from men who have been employed to supervise the works and from the study of books and technical publications. On the other hand, many small plant operators are satisfied to permit the supervising chemist to direct the plant operation and they carry out his orders. It is necessary at all plants treating surface waters that the operator be an intelligent man with some initiative, because it is not possible to operate such a plant by following orders issued once a week by a supervisor. At a softening plant using ground water, the problem is quite different. The supervisor adjusts the treatment for a given type of water with reasonable assurance that the water will remain of uniform quality, with no changes in treatment necessary before his next visit.

Some explanation should be made about the supervision of small plants as it is practiced in Ohio. Regulations of the State Health Dept. require that operators in responsible charge of water purification plants hold one of three grades of certificates issued by the Director of Health. Plants which treat surface waters must have a man in charge who holds either an *A* or *B* certificate, the class required being determined by the size of the plant and the character of the raw water supply. Small plants in which the operator does not have the necessary qualifications for a *B* certificate must be supervised by a man holding an *A* or *B* certificate. The supervisor is then in responsible charge of the plant. How much instruction he gives the plant operator is really a matter between himself and the operator. Some operators are anxious to learn the technical phases of water purification, while others are satisfied to let the supervisor take responsibility for the plant's output. For the most part, however, the operators of small plants make an effort to improve their status by preparing themselves for the examinations which are held annually for the various certificates. This system of supervision of water plants has been in successful operation for more than 25 years in Ohio. The certification of plant operators, however, was begun only eleven years ago.

In an effort to improve filter plant operation, Ohio is following the lead of some other states in establishing a short school for small plant operators. Its first session, held in 1948 at Ohio State University, was largely devoted to elementary and basic training. No decision has been made as to the eventual schedule of training, but the purpose of the school is to raise the operators (through training) to a higher level of competence.

COLOR CODE YOUR PLANT

H. E. LORDLEY
Asst. Director
Dept. of Public Utilities, Richmond, Va.

A NEW word for the progressive plant operator to add to his vocabulary in discussing plant maintenance is COLOR. The superintendent of the smallest pumping station or the largest filtration plant can establish a "color code" for the identification of equipment as well as piping, both to facilitate maintenance and repairs and to improve the general appearance of the plant.

During the war, industrial plant managers realized the importance of proper identification of piping systems when many inexperienced employees were hired. Lack of such identification resulted in many unusual cross connections and costly shut-downs. This hazard was so pronounced that the American Standards Association published on July 16, 1945, a "Safety Color Code for Marking of Physical Hazards and the Identification of Certain Equipment." The plant operator should consult the American Standards Association's publications on the subject or establish his own code, as was done in the Richmond Filter Plant even prior to World War II.

Establishing A Color Code

The first step in any system is to establish a definite color code according to the character of the various materials in the piping system. The ASA system is shown in Table I.

In this system all materials piped are listed and each assigned to one of the five classes, as illustrated in Table II.

TABLE II

Material Piped	Classification
Alum solution	S
Carbon dioxide	D
Chlorine	D
Ammonia	D
Soda ash solution	S
Water	S
Steam	D
Water—fire protection	F

Richmond Markings

Table III illustrates the system used in Richmond for identification of pipes common to water plants. However, this system was established in 1940 and is not always in conformity with ASA recommendations listed above.

The system has the advantage of a larger number of colors and results in a variety of hues in an otherwise monotonous piping system. Many favorable comments have been received from visitors on this color arrangement and particularly from classes of school children.

Methods of Application

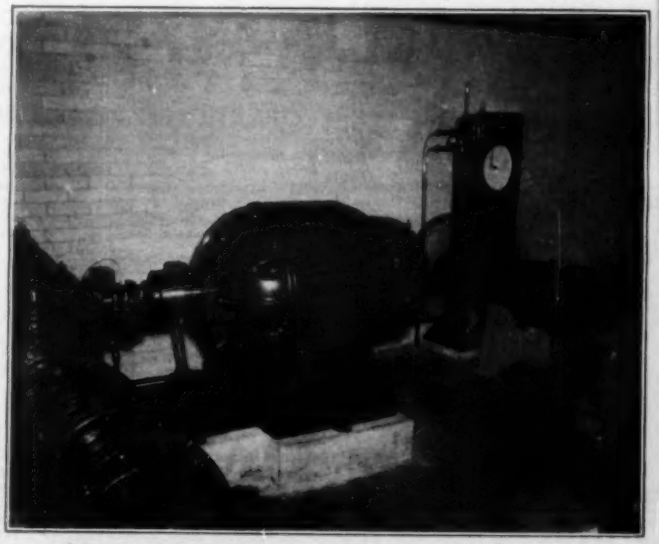
The second step requires careful consideration and study in selecting the actual method of applying the colors selected above. The entire length of pipe, valves and fittings may be painted the designated color, or the alternate method of painting color bands on piping having a uniform color may be used successfully. For example, it is often necessary to paint piping white or aluminum to improve illumination in pipe galleries, basements or dark areas, in which case an identifying color band 8 to 10 inches wide is painted adjacent to each valve, tee or branch pipe. However, the author has found one disadvantage in painting entire lengths without a change. It seems that painters become tired of using one color, which results in less footage per day covered than when switching to different colors. It is also interesting to note that in cases where one or more men are assigned the definite duty of painting their personal interest and pride in the work increases in keeping each line painted the proper color. New employees assigned to painting learn the piping system quickly. Having thus obtained a more thorough knowledge of the plant piping, they make more valuable employees when transferred later to the mechanical maintenance division or the operating division.

TABLE I

Classification	Color
F—Fire protection equipment	Red
D—Dangerous materials	Yellow or orange
S—Safe materials	Green, or the achromatic colors white, black, gray or aluminum
P—Protective materials	Bright blue
V—Extra valuable materials	Deep purple

TABLE III

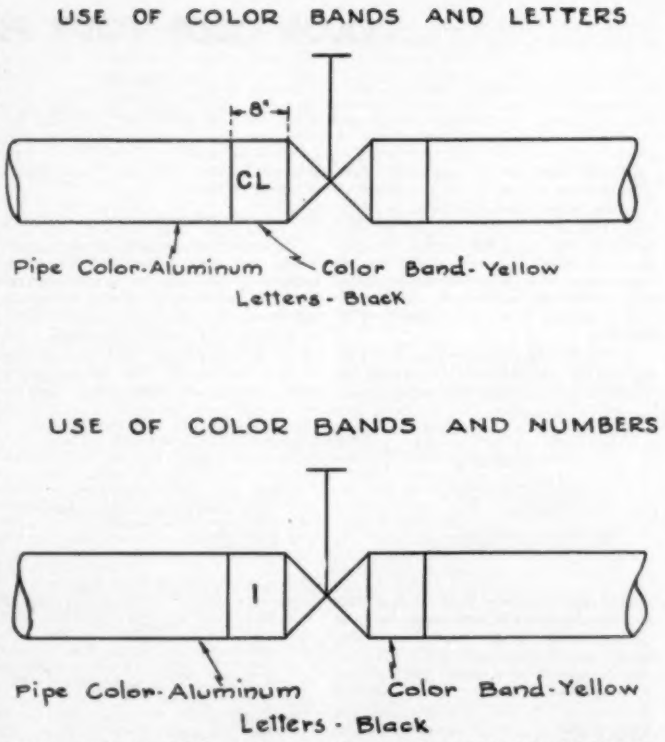
Piping	Color
Fire lines	Red
Sump pump lines	Red with white band
Raw water pumps	Red with white band
Drains on chemical machines	Red with white band
Waste water pump	Red with white band
Finished water	Dark green
Motors	Dark green
Electric conduit	Gray
Steam lines	Black
Chemical lines	Orange
Chlorine (gas or solution)	Yellow
Ammonia (gas or solution)	Yellow
Sulfur dioxide (gas or solution)	Yellow
Sewers	Light blue
Wash water pumps and lines	Light green
Air ducts	Aluminum
Hot water	Aluminum
Venturi meter lines and stacks	Brown



Color Code Paint Job in Fully Automatic Booster Pumping Station.

If a color band system is selected, this can be used in conjunction with stenciled words, letters and figures or more stripes of color at the edges of the band to indicate the exact identification of the system. For example, the uniform color of the system is aluminum with a yellow color band, indicating a dangerous material; however, chlorine, ammonia and sulfur dioxide are all dangerous, and it is necessary to further identify the system by the stenciled letters CL (chlorine), NH (ammonia), SO (sulfur dioxide), or Nos. 1 (chlorine), 2 (ammonia), 3 (sulfur dioxide), as illustrated in the accompanying sketch.

In selecting colors always remember that the reflective value of paints vary with the shade. Gray, which from a physiological or visual standpoint is situated about halfway between white and black, reflects approximately 25% of the incident standard white light, and is near the permissible limit of reflective value for poor illumination. In pipe galleries, aluminum or white paints give maximum illumination and increase the efficiency of maintenance operation.



Sketch Illustrative of Color Band System Used in Valve and Pipe Line Identification.

Selection of Paints

The type and quality of paint used in a plant is often dependent on the judgment of the superintendent, and he is required by the Purchasing Department to submit specifications on every item. Several government publications are available to aid in the difficult job of selecting paint, two of the most useful being—

1) "Paint Manual." Report BMS105, dated October 11, 1945, available from the Superintendent of Documents, Washington 25, D.C., at a price of $1.

2) "Federal Specifications." Price List No. 75, available from the Superintendent of Documents, no charge.

This list includes all specifications available on paint, copies of which may be purchased at the price listed; for example, Specifications TT-P-59 paint, ready mixed, international-orange, June 17, 1937, price 5c.

Our experience with the color code in Richmond has been more than satisfactory, and we have included the code in the specifications for our new thirty-six million gallon per day plant now under construction.

PROPORTIONING CONCRETE

Proportions of Mixtures			Material For One Cubic Yard Concrete								
			Gravel ¾" and under			Stone 1" and under, dust screened out			Stone 2½" and under, dust screened out		
Cement	Sand	Stone	Cement Bbls.	Sand Yards	Stone Yards	Cement Bbls.	Sand Yards	Stone Yards	Cement Bbls.	Sand Yards	Stone Yards
1	2	3	1.54	.47	.73	1.70	.52	.77	1.73	.53	.79
1	2	4	1.34	.41	.81	1.46	.44	.89	1.48	.45	.90
1	2	5	1.17	.36	.89	1.27	.39	.97	1.29	.39	.98
1	2¼	4	1.24	.47	.75	1.35	.52	.82	1.38	.53	.84
1	2½	5	1.10	.42	.83	1.19	.46	.91	1.21	.46	.92
1	2½	6	.98	.37	.89	1.07	.41	.97	1.07	.41	.98
1	3	5	1.03	.47	.78	1.11	.51	.85	1.14	.52	.87
1	3	6	.92	.42	.84	1.01	.46	.92	1.02	.47	.93
1	3	7	.84	.38	.89	.91	.42	.97	.92	.42	.98
1	4	6	.83	.51	.77	.90	.55	.82	.92	.56	.84
1	4	7	.77	.47	.81	.83	.51	.89	.84	.51	.90
1	4	8	.71	.43	.86	.77	.47	.93	.78	.48	.95
1	4	9	.65	.40	.89	.71	.43	.97	.73	.46	1.01

1 Bag of Cement ..... = 94 Lbs. 4 Bags of Cement..... = 1 Bbl.
1 Bag of Cement ..... = 1 Cu. Ft. 1 Bbl. of Cement..... = 400 lb. Gross, 376 lb. Net

SPORICIDAL PROPERTIES OF CHLORINE DIOXIDE

G. M. RIDENOUR[1], R. S. INGOLS[2], E. H. ARMBRUSTER[3]
University of Michigan, Ann Arbor, Mich.*

PREVIOUS studies[1] [2] [3] have shown that chlorine dioxide possesses both bactericidal and virucidal properties as measured against E. coli, common water pathogens and mouse adapted poliomyelitis virus. In the aforementioned studies chlorine dioxide gave results comparable with chlorine on an OTA basis of residual measurement. The non-spore forming bacteria are of first importance since they include the principal etiological agents of water borne disease. However, spore forming organisms are also a source of annoyance in water supplies by providing inoculation for after-growths in water distribution systems.

The investigations have hence been extended to collect information on the sporicidal properties of chlorine dioxide in relation to both free chlorine and chloramines, as a complement to the information on the non-spore forming bacteria and virus.

METHODS OF STUDY

Information on the sporicidal properties of chlorine dioxide, in relation to free chlorine and chloramines, was sought with the use of the spore forming bacteria, B. subtilis, B. megatherium, and B. mesentericus. The sporicidal effect of chlorine dioxide was compared to that of "free chlorine" from two sources; one (Method A), the "free chlorine" from an ammonia bearing spore suspension chlorinated beyond the breakpoint, the other (Method B), from gaseous chlorine solution added directly as "free chlorine" to an ammonia free and organic free spore suspension.

The chlorine dioxide gas was prepared by scrubbing out acid treated sodium chlorite into water. This was used as the working stock solution. Chlorine was similarly prepared, except that sodium hypochlorite was used for generating the chlorine gas. Chloramines were obtained by adding chlorine to the working spore suspension that contained ammonia.

All working solutions were buffered to maintain a pH between 7.0 and 7.5. Chemical measurements of the disinfectants were made by means of iodide starch titration, acid orthotolidine (OT) and orthotolidine-arsenite (OTA). Temperature was maintained between 60° to 68°F. Time of disinfection contact varied between 10 and 30 minutes depending on the specific study. Peptone thiosulfate dilution water was used as a neutralizer to stop the action of chlorine or chlorine dioxide at the end of the desired contact period. The possible presence of bacteriostasis was checked in each instance by reinoculating neutralized solutions with viable spores.

Specific Methods

Method A: Under this method the sporicidal properties of chlorine dioxide were compared to chloramines and "free chlorine", by treating a water containing ammonia and peptone below and beyond the breakpoint.

A series of ten tests were made with B. subtilis; five tests with B. mesentericus; and three tests upon B. megatherium. Each of the test spores were prepared by inoculating a number of nutrient agar slants and incubating the culture until spore forms were predominant as indicated by microscopic examination. The spores were then washed off with sterile water and the suspension boiled to destroy vegetative forms. The boiled suspension was diluted with a buffered water containing 10 ppm. NH_3-N and 50 ppm. peptone. The buffer capacity was necessary to maintain the pH between 7.0 and 7.5 in the presence of high chlorine doses. The ammonia was used to obtain a breakpoint with chlorine. Peptone was used to produce a chlorine dioxide demand. An aliquot of diluted spore suspension was added to each of a series of glass stoppered flasks and increasing amounts of chlorine and chlorine dioxide added to each. After 5 minutes contact, 1 ml. of the suspension was transferred to 99 ml. thiosulfate dilution water. Nutrient agar plates were then poured at appropriate dilutions. At the same time the spore transfers were being made, chlorine residuals were determined by orthotolidine, orthotolidine-arsenite, and iodide methods. Similar transfers and residuals were also repeated after 30 min. contact. Counts of spores vegetating were made after 48 hours incubation.

Method B: Under this second method of study the relative sporicidal efficiencies of chlorine dioxide and chlorine were studied on a spore suspension in a medium free from ammonia, organic matter, or other chlorine or chlorine dioxide demand substances, except that caused by the reaction with the spores themselves or the vegetative cells in the suspension that were destroyed before the tests were made. The general procedure for testing was similar to that used in Method A, except that chlorine demand and ammonia free water was used as the suspending medium for the test spores and extra precautions taken to free the suspension solution of ammonia and organic matter. To do this, the 20-day slants of B. subtilis and B. mesentericus were washed with 10 ml. of saline to form a suspension of both cells and spores. This suspension was then washed with fresh saline by centrifugation to remove organic matter. The spores were resuspended and held at 80°C. for 20 minutes to kill vegetative cells and spores of lesser resistance and the surviving spores were then added to four liters of buffered ammonia and chlorine demand free water and thoroughly mixed. This preparation was used as the test suspension.

RESULTS OF STUDY

Method A: A typical set of results from this method of testing, which compares chloramines, breakpoint "free chlorine" and chlorine dioxide on the spores of B. subtilis, B. mesentericus, and B. megatherium is plotted in Figs. 1, 2, and 3.

These test results indicate that for an equal degree of spore kill, lesser OTA residuals are required from chlorine dioxide than from chlorine. As, for example, in Fig. 1, for B. subtilis, a 99 percent reduction resulted from the presence of 0.1 ppm. of chlorine dioxide as against a required OTA residual of 2.5 ppm. from chlorine after the breakpoint. For B. mesentericus, the relative OTA residual concentration for the same kill were 2.0 ppm. for chlorine dioxide and 10.0 ppm. for chlorine. For B. megatherium the respective residuals for the same kill were 0.3 and 3.5 ppm. This same relative tendency is shown in other separate runs on the same spores.

Method B: The results of the tests where the sporicidal effect of chlorine dioxide on pure spore cultures suspended in a chlorine and chlorine dioxide demand free medium were studied, is shown in Fig. 4.

The results in this set of data showing the sporicidal effect of chlorine dioxide and the relative effect of "free" chlorine are roughly analogous to the data under Method A, where the free chlorine residual beyond the breakpoint was compared with chlorine dioxide.

These results show, as in the previous data, that chlorine dioxide is a sporicide if used in the proper concentrations. The OTA residuals required by chlorine dioxide were less than those by chlorine for equal degree of kill. As an example, for 99.9 percent kill of B. mesentericus, an OTA residual from chlorine dioxide of 2.0 ppm. was required. Chlorine OTA residual required was over 10 ppm. For B. subtilis, chlorine dioxide required approximately 1.0 ppm. residual and chlorine required a residual of 3.5. In terms of weight of gas applied, 5.5 ppm. of chlorine dioxide and 12.5 ppm. of chlorine was required for 99.9 percent kill of B. mesentericus; for B. subtilis, 3.0 and 6.3 ppm. were respectively required. This same relative tendency of chlorine dioxide and chlorine held true for all degrees of kill down to sterility. However, the divergence between the two gases increased as sterility was approached.

Comparison of Results from Methods A and B

A summarized version of the results of the studies under Methods A and B would be as shown in Table I.

Discussions

The data in this paper cannot necessarily be used, nor is it intended to be used for interpretation as to the proper general sporicidal concentrations of either chlorine dioxide or chlorine. Different sporulating organisms and individual organisms within the same species may differ in their resistance to disinfectants depending on the conditions which cause sporulation and more especially the severity of conditions. Therefore, individual bacteria in the same strain may show different tolerance levels to disinfectants.

The specific purpose of these studies has been to show whether chlorine dioxide does or does not possess sporicidal properties, and if so, how it might compare with "free chlorine" when used for such purposes in water treatment.

With this in mind, the major conclusions that can be drawn from these studies are that on the basis of OTA residuals chlorine dioxide is more effective as a sporicide than chlorine. That is, with the same O.T.A. residual existing in two solutions, one chlorine and the other chlorine dioxide, the solution containing chlorine dioxide more effectively destroys the spores. This phenomenon is apparently due to the fact that atom per molecule, chlorine and chlorine dioxide seem to act sporicidally much the same but the O.T.A. measures only one-

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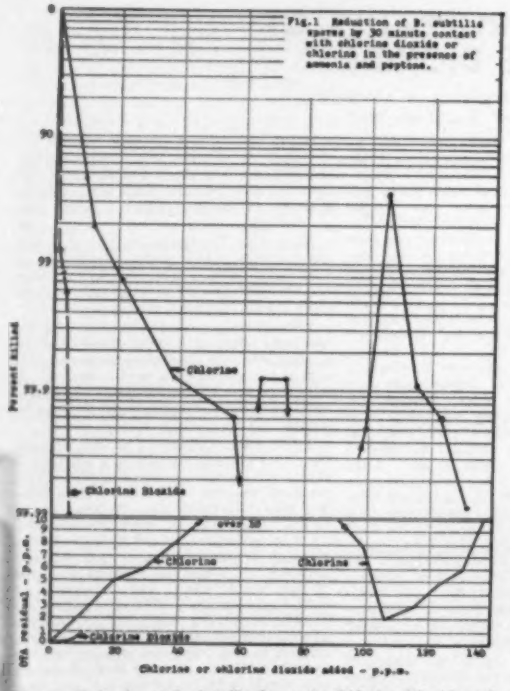
Fig.1 Reduction of B. subtilis spores by 30 minute contact with chlorine dioxide or chlorine in the presence of ammonia and peptone.
Percent Killed
Chlorine
Chlorine Dioxide
O.T.A. residual - p.p.m.
over 10
Chlorine
Chlorine
Chlorine Dioxide
Chlorine or chlorine dioxide added - p.p.m.

Fig. 1.—Reduction of B. Subtilis Spores by Chlorine Dioxide and Chlorine in 30 minutes (In presence of ammonia and peptone)

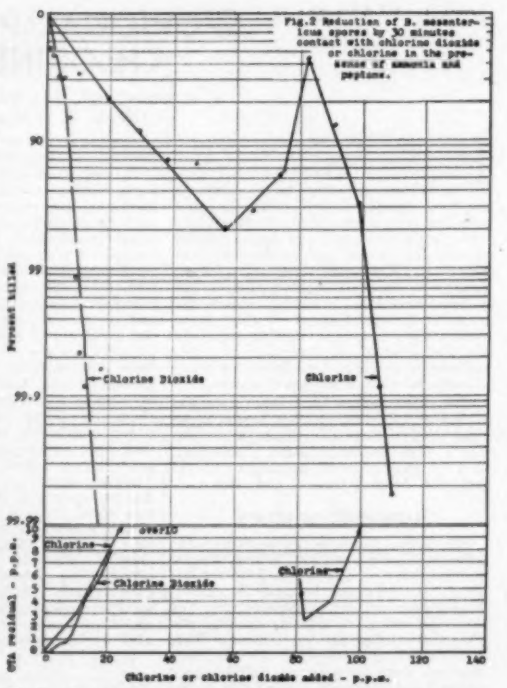
Fig.2 Reduction of B. mesentericus spores by 30 minutes contact with chlorine dioxide or chlorine in the presence of ammonia and peptone.
Percent Killed
Chlorine Dioxide
Chlorine
O.T.A. residual - p.p.m.
over 10
Chlorine
Chlorine Dioxide
Chlorine
Chlorine or chlorine dioxide added - p.p.m.

Fig. 2.—Reduction of B. Mesentericus Spores by Chlorine Dioxide and Chlorine in 30 minutes (In presence of ammonia and peptone)

fifth of chlorine dioxide potential valence change.

This difference in effectiveness between O.T.A. residuals of chlorine and chlorine dioxide on spores is much greater than on vegetative cells where the effect of O.T.A. residuals from each of the two gases seems to be approximately the same. The difference may be due to the lack of five full valence changes from chlorine dioxide in the case of the vegetative cells, whereas the chlorine dioxide is more reactive with the spore material and utilizes its entire potential oxidizing capacity to a fuller extent.

The amount of chlorine or chlorine dioxide needed to effect kill depends on the relative characteristics of the water with respect to chlorine or chlorine dioxide demands, types of chloro-compounds formed, etc. These data show, however, that in either chlorine and chlorine dioxide demand free waters, or in waters containing ammonia, less chlorine dioxide is needed than chlorine by weight, for a given kill of spores. In the former instance the result is due to the more effective action of the OTA residual from chlorine dioxide. In the latter, less weight is required not only by reason of the greater effectiveness of the same OTA residual, but also because chlorine dioxide is unreactive with ammonia.

It would appear from these data that chlorine dioxide could be used in water plant practice not only for the control of tastes and odors but also for the better control of spore contamination. If the spores which normally cause aftergrowth in water mains are as easily destroyed as the B. subtilis, then ordinary plant residuals from chlorine dioxide would give quite effective control of aftergrowths, due to spore contamination, in the water plants and systems.

Summary and Conclusions

Laboratory studies were made to obtain information on possible sporicidal properties of chlorine dioxide with the view of determining the potential application of the gas toward eliminating the annoyance of aftergrowths from spores in water plants and distribution systems. These studies were related to the effectiveness of chlorine for the same purpose, under the same conditions.

Results of these studies may be summarized as follows:

1. Chlorine dioxide is a more effective sporicide than chlorine if compared on equal OTA residual basis.
2. The effectiveness of OTA residual from chlorine dioxide as related to chlorine seems to be greater on spores than on vegetative cells. The difference may be due to the residual potential of four additional valence changes in the chlorine dioxide molecule which, on spores, may be more effective because of a more reactive nature of the spore material with the chlorine dioxide molecule.
3. Less weight of chlorine dioxide than chlorine is required in either demand free waters or in waters containing ammonia. The difference in weight required depends on the ammonia content. In ammonia bearing waters, chlorine must be applied beyond the breakpoint before sporicidal efficiency is obtained equal to that from chlorine dioxide.
4. It would appear from these investigations that chlorine dioxide could be used

TABLE I

Summary of Relative Sporicidal Effects of Chlorine and Chlorine Dioxide in the Absence or Presence of Ammonia

Under Method A with Ammonia

OTA residual ("Free Chlorine" equivalent) to obtain 99% kill in 30 Minutes

Organism	(Before Breakpoint) O.T.A. residual	(Beyond Breakpoint) O.T.A. residual	(Chlorine Dioxide) O.T.A. residual
B. subtil's	6.5	2.2	0.1
B. mesentericus	over 10	over 10	1.6
B. megatherium	over 10	3.5	0.3

Under Method B with Ammonia Free and Demand Free Medium

Amount in ppm. to obtain 99% kill in 10 minutes

Organism	(Chlorine)		(Chlorine dioxide)	
	Weight	O.T.A. residual	Weight	O.T.A. residual
B. subtilis	4.3	2.5	2.6	0.6
B. mesentericus	10	8	3.3	1.0

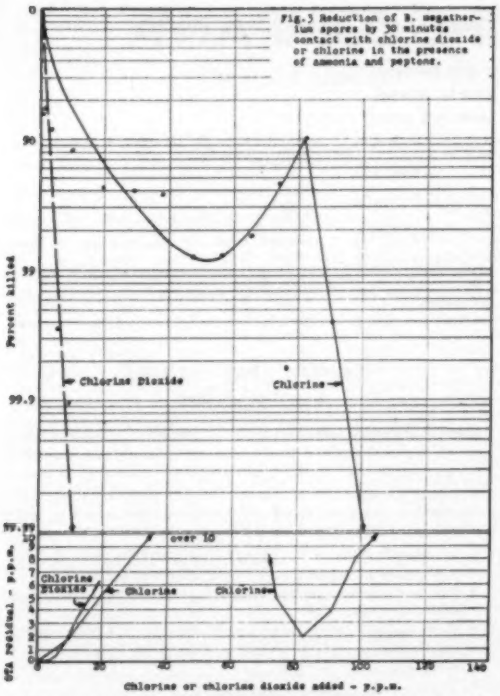
Fig. 3 Reduction of B. megatherium spores by 30 minutes contact with chlorine dioxide or chlorine in the presence of ammonia and peptone.
Percent killed
Chlorine Dioxide
Chlorine
Cfu residual - p.p.m.
over 10
Chlorine Dioxide
Chlorine
Chlorine
Chlorine or chlorine dioxide added - p.p.m.

Fig. 3.—Reduction of B. Megatherium Spores by Chlorine Dioxide and Chlorine in 30 minutes (In presence of ammonia and peptone)

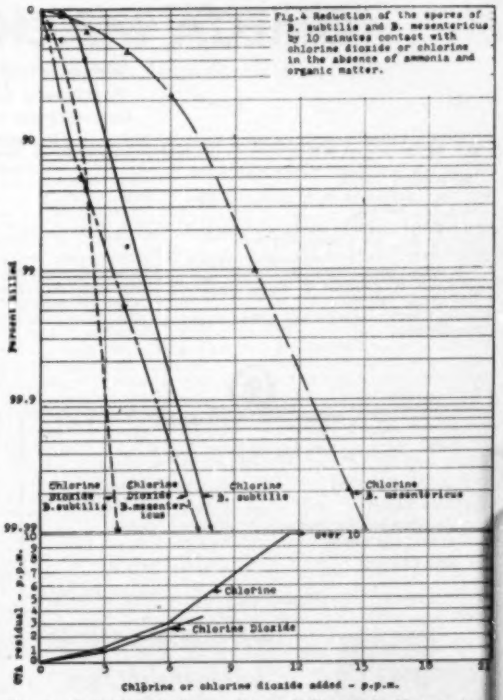
Fig. 4 Reduction of the spores of B. subtilis and B. mesentericus by 10 minutes contact with chlorine dioxide or chlorine in the absence of ammonia and organic matter.
Percent killed
Chlorine Dioxide B. subtilis
Chlorine Dioxide B. mesentericus
Chlorine B. subtilis
Chlorine B. mesentericus
Cfu residual - p.p.m.
over 10
Chlorine
Chlorine Dioxide
Chlorine or chlorine dioxide added - p.p.m.

Fig. 4.—Reduction of Spores of B. Subtilis and B. Mesentericus by Chlorine Dioxide and Chlorine in 10 minutes (In absence of ammonia and organic matter)

in water plant practice for the control of spore contamination in either water treatment plants or in water distribution systems. Under conditions where the ammonia content of the water requires breakpoint application of chlorine for control of spores, chlorine dioxide may offer a decidedly superior method of treatment.

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2. Ridenour, G. M., and Armbruster, E. H. "Bactericidal Effect of Chlorine Dioxide on Some Common Water Pathogens and Other Organisms." *Jr. A.W.W.A., 41, 537 (1949).*

3. Ridenour G. M. and Ingols R. S. "Inactivation of Poliomyelitis Virus by 'Free' Chlorine." *Am. J. of Pub. H. 36, 659 (1946).*

Metric Conversion Table

Millimeters × .03937 = inches.
Millimeters ÷ 25.4 = inches.
Centimeters × .3937 = inches.
Centimeters ÷ 2.54 = inches.
Meters × 39.37 = inches (Act of Congress).
Meters × 3.281 = feet.
Meters × 1.094 = yards.
Kilometers × .621 = miles.
Kilometers ÷ 1.6093 = miles.
Kilometers × 3280.8083 = feet.
Square Millimeters × .00155 = sq. inches.
Square Millimeters ÷ 645.1 = sq. inches.
Square Centimeters × .155 = sq. inches.
Square Centimeters ÷ 6.451 = sq. inches.
Square Meters × 10.764 = sq. feet.
Square Kilometers × 247.1 = acres.
Hectare × 2.471 = acres.
Cubic Centimeters ÷ 16.383 = cubic inches.
Cubic Centimeters ÷ 3.69 = fl. drams (U. S. P.).
Cubic Centimeters ÷ 29.57 = fluid ounces (U.S.P.).
Cubic Meters × 35.313 = cubic feet.
Cubic Meters × 1.308 = cubic yards.
Cubic Meters × 264.2 = gallons (231. cubic inches).
Liters × 61.022 = cu. in. (Act of Congress).
Liters × 33.84 = fluid ounces (U. S. P.)
Liters × .0346 = gallons (231. cu. in.).
Liters ÷ 3.78 = gallons (231. cu. in.).
Liters ÷ 28.316 = cubic feet.
Hectoliters × 3.531 = cubic feet.
Hectoliters × 2.84 = bushels (2150.42 cu. in.).
Hectoliters × .131 = cubic yards.
Hectoliters ÷ 26.42 = gallons (231. cu. in.).
Grams × 15.432 = grains (Act of Congress).
Grams ÷ 981. = dynes.
Grams (water) ÷ 29.57 = fluid ounces.
Grams ÷ 28.35 = ounces avoirdupois.
Grams per Cu. Cent. ÷ 27.7 = lbs. per cubic inch.
Joule × .7373 = foot pounds.
Kilograms × 2.2046 = pounds.
Kilograms × 35.3 = oz. avoirdupois.
Kilograms ÷ 907.2 = tons (2,000 lbs.)
Kilograms per Sq. Cent. × 14.223 = lbs. per sq. in.
Kilogram-meters × 7.233 = foot lbs.
Kilograms per Meter × .672 = lbs. per foot.
Kilograms per Cu. Meter × .062 = lbs. per cubic foot.
Tonneau × 1.1023 = tons (2,000 lbs.).
Kilowatts × 1.34 = Horse Power.
Watts ÷ 746. = Horse Power.
Watts × .7373 = foot pounds per second.
Calorie × 3.968 = B.t.u.
Cheval vapeur ÷ .9863 = Horse Power.
(Centigrade × 1.8) + 32 = degrees Fahr.
Gravity Paris = 980.94 centimeters per sec.

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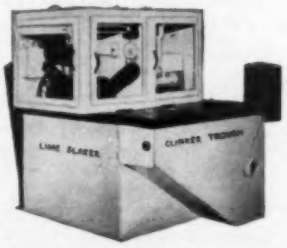

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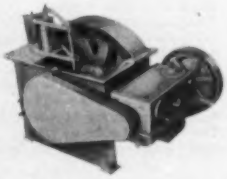

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FLUORIDATION OF PUBLIC WATER SUPPLIES

Data and Opinions on this Experiment in Mass Medication

By HARRY A. FABER†
Research Chemist
The Chlorine Institute, Inc., New York, N.Y.

THE practice of fluoridation is unique among methods for the treatment of public water supplies. It is unique because it is an additive rather than a subtractive method. All other methods of water treatment, applied for the protection of public health, have been devised to reduce excessive concentrations of constituents present in natural waters. Fluoridation is employed to increase inadequate concentrations of a constituent present in natural waters. There is little difference in principle between fluoridation and other methods of treatment, but there is a considerable difference in philosophy.

In its general attitude toward this unique method of water treatment, the water works industry will do well to recognize, as did Wolman in his foreword to "The Quest for Pure Water," that: "Neither the consumer nor the professional should be disconcerted by this endless adventure in search for 'pure' water. It is the natural concomitant of advancing knowledge and expanding horizon." The specific attitude of the water works industry, however, will be determined by factual information regarding the present status of water fluoridation. It is the purpose of this paper to present such information in summary form.

The Background

The basic evidence demonstrated by carefully conducted epidemiological studies is this: In communal water supplies minimum concentrations of naturally occurring fluoride ion are desirable and excessive concentrations are detrimental. The range between the limiting concentrations is very narrow.

The existence of the fluoride ion in drinking water was discovered less than twenty years ago, and it was soon recognized that excessive concentrations of this ion were the cause of fluorosis or mottled tooth enamel[1]. Subsequent investigations have established 1.5 ppm. fluoride as the maximum concentration which does not produce fluorosis. With higher concentrations mottled tooth enamel becomes increasingly more severe; at 6.0 ppm. almost every child will be affected.

Much study has been given to the development of methods for the treatment of water to remove the fluoride ion. Fluoride removal methods so far developed are extremely costly to install and operate. More than 350 public water supplies in the United States are reported to contain excessive concentrations of fluoride ion, and fluoride removal treatment is provided in only 10 of these.

In 1938 studies by Dean disclosed the existence of an inverse ratio between dental caries (tooth decay) in children and the fluoride content of the communal water supply[2]. His results showed dental caries experience to be at a minimum when the water contained 1-1.5 ppm. fluoride. This concentration of fluoride ion was found, by examination of over 7,000 school children, to be associated with a 50 to 65 per cent reduction in caries prevalence. The relation is illustrated in Fig. 1.

Evidence of the relation between dental caries and the fluoride content of water supplies has been largely based upon studies of children. There have been few data concerning the dental health of adults who were exposed to fluoride-containing water during childhood. The results of a study by McKay provides some evidence that the inhibitory effect of fluoride, once acquired, may be permanent. His study was based on the examination of 400 adults who were natives of Colorado Springs, Colo., where the water supply has a natural fluoride content of 2.6 ppm. and has been in use for about 70 years[3]. While these adults were found to have mild dental fluorosis, they exhibited an unusually low rate of permanent tooth loss. A comparison of the findings with the normal expectancy of tooth loss for the United States is illustrated in Fig. 2.

The Theory

An inverse relationship appears to exist between the fluoride content of natural waters and the prevalence of dental caries. Recognition of this relationship led to the proposal that fluoride be added, as a caries control measure, to waters deficient in that constituent.

The control of caries by adding fluoride to a public water supply is based on the hypothesis that the water so treated will have the same effect as one naturally containing fluoride. This hypothesis appears justified by chemical and biological considerations, by laboratory research, and by epidemiological evidence.

At least eight years will be required before a preliminary indication of the full effect of fluoridated water on dental caries can be determined; that is, until children have used fluoridated water throughout the period of tooth enamel formation (through age eight for all teeth except the third permanent molars).

The validity of the hypothesis can be tested only by carefully controlled experimental studies[4]. Several studies of this nature are now under way, generally planned on an 8-10 year basis, and directed by specialized technical personnel. The application of fluoride is made under the supervision of the State Department of Health. Dental and medical studies are made of children in the community, and another community having a similar water supply low in fluoride content is studied as a control.

In the United States, the first experimental studies of water fluoridation were inaugurated in 1945; in January at Grand Rapids, Mich., and in May at Newburgh, N.Y. Both cities employ sodium fluoride as the source of the fluoride ion.

Fluoridation Studies Being Made

In New York State, for example, the neighboring cities of Newburgh and Kingston are participating in the study. Each city has a population of about 30,000, which is fairly similar as to race and economic status. The raw water supplies of the two cities are very much alike in chemical composition, that of Kingston containing about 0.05 ppm. fluoride and that of Newburgh being treated to contain about 1.0 ppm. fluoride. Composite samples are collected daily for fluoride analysis to control the treatment process. A dental examination of all children 5 to 14 years of age was made by the State Health Department at the outset of the study and is to be repeated annually.

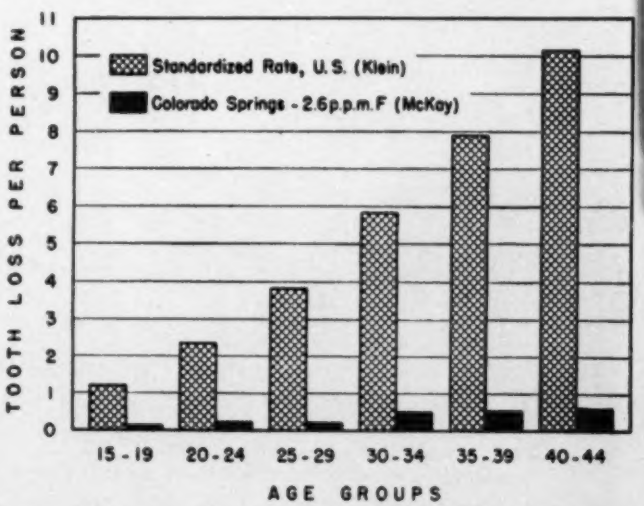


Fig. 1.—Comparison of Tooth Loss at Colorado Springs with "Standardized Rate" —(From H. T. Dean)

†Editorial Associate, Water & Sewage Works, New York City.

The treatment of a water supply with fluoride is a simple procedure. The form of fluoride applied is commercial sodium fluoride. The fluoride content of this salt is such that a dose of 1.0 ppm. fluoride ion requires the addition of 2.2 ppm. of sodium fluoride. That is, approximately 18.4 pounds of pure sodium fluoride must be used in order to provide a dose of 1.0 ppm. fluoride ion.

Sodium fluoride is readily soluble in water and is generally applied by means of a dry feed device. For relatively small volumes of water, the dry feed device must be especially designed to feed accurately at low rates. The sodium fluoride is discharged as fed into a minor flow of water in a dissolving unit, and the solution flows by gravity into the major flow of water. Water under pressure may be treated by using, to apply fluoride solution, one of the small chemical solution pumps designed for feeding hypochlorite solutions. At one treatment plant, hydrofluoric acid is employed as the source of fluoride.

The test for residual fluoride in water is a relatively simple colorimetric procedure[10], based on the Scott modification of the Sanchis method. The chloride ion does not interfere in this test up to a limit of 500 ppm. However, a free available chlorine residual is reported to interfere in the test for residual fluoride, and methods have been devised to reduce this interference. In order to prevent any loss of added fluoride by coagulation and filtration, the fluoride is added to water following filtration.

Tooth Decay and the Function of Fluoride

As far back as historical records go, it is known that human beings have been subject to dental disease. Tooth decay is mentioned in the most ancient of all known works on medicine, written about 37 centuries B.C., and probably toothache has existed as long as mankind. The control of dental caries is the fundamental problem of modern dentistry. This problem is complicated by the fact that dental enamel, once injured, is incapable of self-repair.

The need for corrective measures is so great that the American dental profession, now grown to approximately 70,000 practitioners, finds that dental caries is developing faster than it can be treated. Of the first 2 million men examined for the army in the second world war, the chief single cause for rejection was dental defects. During 1941, about 500 million dollars was spent for dental services in the U.S. Despite this vast expenditure these services were rendered to a portion of the population only, the majority of people receiving either no dental services or merely extractions.

While progress has been made in explaining how dental caries occurs, the prevention of decay still awaits either new conceptions or further proof of present promising explanations. There have been numerous articles published within the last ten years which began, "We do not know the cause of dental caries." The authors then continued learnedly, but unconvincingly, to lecture the reader on the proper means to assure protection from this disease (cause unknown). The public has been advised to utilize vitamins, lime, phosphates, minerals, chewing gum, quinones, antibiotics, amonia, urea, mouth washes, dentifrices, tooth brushing, alkaline diets, protein diets, uncivilized diets, sugar-free diets, or to live an emotionally stable existence.

On the basis of research carried out nearly fifty years ago, and supported by recent investigations, the opinion of the American Dental Association appears to be as follows[9]: "Dental caries is caused by acids resulting from the action of micro-organisms on carbohydrates, is characterized by a decalcification of the inorganic portion, and is accompanied or followed by a disintegration of the organic substance of the tooth." Certain bacteria, particularly Lactobacillus acidophilus, have long been considered implicated in causing dental decay. It has been considered that small amounts of fluoride in water suppress the production of acid by this organism, though not necessarily inhibiting its growth[9].

It has very recently been reported, however, that the formation of acid from carbohydrates in the mouth is enzymic in nature, and that the reaction is extremely rapid in nature[7]. On this basis, it is obvious that the decay of teeth is not a long, continual, and gradual decalcification, but rather a series of intensive reactions. All of the acid is derived from the carbohydrate left in the mouth, and is not related to the amount swallowed. It appears, therefore, that the control of dental decay depends upon inhibiting the rapid formation of acid.

This can be accomplished by applying a chemical which will inhibit the enzyme activity and thus correspondingly reduce the formation of acid from carbohydrates. At present the only known inhibitor, which is retained for appreciable periods of time, is the fluoride ion. This action is not purely inhibitory, but is also dependent upon a change which is produced in the solubility of the tooth enamel. Any other enzyme inhibitor must be applied during the ingestion of food or immediately thereafter, and is, therefore, not practical.

It is for this reason that the application of fluoride to drinking water may be considered a major step in the control of dental caries, because the individual will thus apply an enzyme inhibitor constantly, and with no additional effort on his part. However, the fluoride ion is not considered an ideal inhibitor. It is too toxic to apply in sufficient concentration to stop all acid formation. Thus, only partial inhibiting action can be expected within practical limits of fluoride application. It is quite possible, nevertheless, that a 10 per cent reduction of acid formation will prevent 60 to 90 per cent of dental decay. This is because it is only necessary to slow down the process of acid formation to the extent that the normal neutralizing influences in the mouth can cope with the situation.

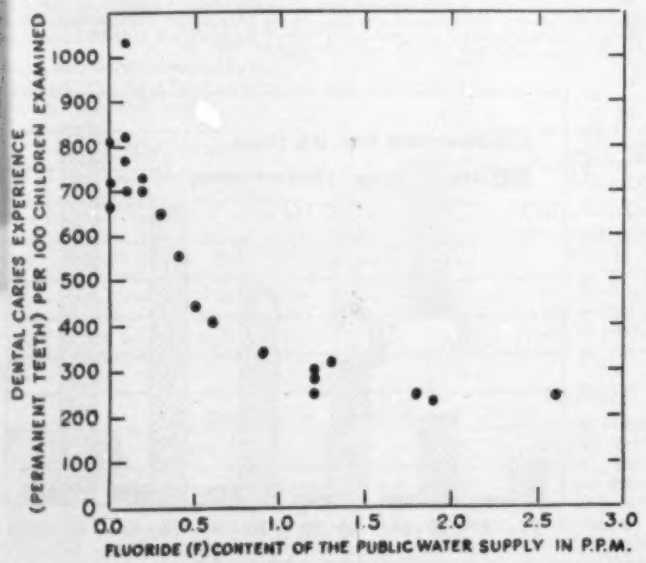


Fig. 2.—Relation Between Amount of Dental Caries (Permanent Teeth) and Fluoride Content of Public Water Supply.—(From H. T. Dean)
(Observations on 7,257 selected 12-14 year old white children of 21 cities in 4 states.)

Official Attitudes

Up to the present year, the attitude of the water works industry toward fluoridation treatment was generally in accordance with the summary presented by Wolman in 1943, and by his four guiding principles suggested in 1947[10]. Briefly, this attitude approved the carefully controlled experimental studies, but recommended the avoidance of more general adoption of fluoridation until the completion of the controlled experimental studies.

The American Water Works Assn. in 1949, gave official acceptance to the practice of water fluoridation for the purpose of reducing tooth decay. A statement of recommended policy and procedure, approved by the Board of Directors of the Association, was presented on June 1st at the Annual Conference in Chicago by A. P. Black, Chairman, Special Committee on A.W.W.A. Policy re: Fluoridation of Public Water Supplies. The statement is printed in full, as an appendix following this article. Official sanction by the A.W.W.A. of the practice of water fluoridation may be expected to have considerable influence on the future development of this practice.

Definition of Terms

The committee statement explains, but does not define, the terms *experimental* and *empirical*. In the practice of this treatment, the following definitions would appear to be suitable:

Experimental Installations: Those in which fluoride is applied to water under controlled

conditions, with the concurrent use of scientific methods to test the fluoride-caries relationship.

Empirical Installations: Those in which fluoride is applied to water under controlled conditions, without the concurrent use of scientific methods to test the fluoride-caries relationship.

Results of Fluoridation Survey

Ultimate jurisdiction over the treatment of a public water supply is vested in the state health authority. It is clear that a program of water fluoridation can properly be undertaken only with the approval of that authority. Accordingly, the general attitude of the state in respect to water fluoridation will have an important influence on the future development of this practice.

A survey has been made by the author to determine the water fluoridation policy of the various state health authorities. A questionnaire was sent to the Chief Sanitary Engineer of each state, and replies were received from all 48 states. The cooperation of these individuals has made it possible to present a comprehensive summary of the status of water fluoridation as of August, 1949.

State Policy: Approximately 40 per cent of the states have adopted a definite policy regarding the fluoridation of public water supplies, and 70 per cent of the states consider the A.W.W.A. Statement of Policy acceptable. All of the states which may give approval to experimental installations, however, are not willing to approve empirical installations. Replies from the 48 states show:

19 have adopted a policy regarding fluoridation.
33 consider the A.W.W.A. Statement of Policy acceptable.
34 may give approval to Experimental installations.
27 may give approval to Empirical installations.

State Procedure: Only one-third of the states have adopted a definite procedure regarding the fluoridation of public water supplies, but 70 per cent of the states consider the A.W.W.A. Statement of Procedure acceptable. A maximum fluoride ion concentration of 1.5 ppm. would be permitted by twenty-two states. Replies from the 48 states show:

16 have adopted a procedure regarding fluoridation.
33 consider the A.W.W.A. Statement of Procedure acceptable.
7 would permit a maximum of 1.0 ppm. F.
1 would permit a maximum of 1.1 ppm. F.
3 would permit a maximum of 1.2 ppm. F.
22 would permit a maximum of 1.5 ppm. F.

Present Fluoridation Installations: A total of 17 fluoridation installations are in operation in the public water supplies of 9 states; each of seven states has one installation, one state has two installations, and one state has eight installations. Eleven of the installations are classified as experimental and six as empirical. The location of these installations is shown in Table I.

TABLE I

Public Water Supply Data
Fluoridation Installations

State	Experimental	Empirical	Total
Idaho	1		1
Illinois	1		1
Kansas	1		1
Michigan	1	1	2
New Jersey	1		1
New York	1		1
North Carolina	1		1
Texas	1		1
Wisconsin	3	5	8
	11	6	17

A total of 3 fluoridation installations are in operation in institutional water supplies of 2 states; all of these are experimental installations. The location of these installations is shown in Table II.

TABLE II

Institutional Water Supply Data
Fluoridation Installations

State	Experimental	Empirical	Total
Connecticut	1		1
Massachusetts	2		2
	3		3

Future Fluoridation Installations: The growth of public water supply fluoridation is indicated by installations which have already been approved by state health authorities or which are now under consideration by them. A total of 14 fluoridation installations are reported to be already approved, and a total of 20 installations are under consideration. The location of these installations is shown in Table III below.

TABLE III

Public Water Supply Data
Future Fluoridation Installations

State	Already Approved	Under Consideration
Arkansas	1	
Colorado	2	
Connecticut		3
Delaware		1
Florida	1	1
Kansas		1
Michigan	3	
New Jersey	1	
New York	1	3
North Dakota		2
South Carolina		1
South Dakota		1
Texas	1	1
Virginia		1
Wisconsin	4	4
Wyoming		1
TOTAL	14	20

Effect of Fluoridation

Grand Rapids, Mich.: It is considered that positive evidence of the effect of fluoridation in reducing dental caries has not been produced in the four and one-half years of experience at Grand Rapids. The Chief of the Public Health Dentistry Section, State Department of Health, states[19]: "I do not see how we can obtain any tangible evidence from Grand Rapids for another three or four years. The children must use the treated water during the period of permanent tooth formation, which is from birth through eight years of age, and these teeth must then be erupted into the mouth where they can be examined. Only then can any definite conclusions be drawn."

Newburgh, N.Y.: Dental findings in the Newburgh-Kingston project have recently been reported[20] by the Chief of the Dental Health Section, State Dept. of Health. The data relate to comparative trends in DMF (decayed, missing, filled) teeth of children in the group 6 to 12 years of age. Examinations included 3400 children in Newburgh, all assumed to have been continuously exposed to fluoridated water for a period of three years, and 2800 children in Kingston where the water is not fluoridated.

The DMF experience rate in Newburgh averages 30 per cent lower than in Kingston among children of this age group. Rates of DMF experience were found to be similar in the two cities during the first post-fluoridation year, but to be consistently lower thereafter in Newburgh than in Kingston. The major benefit of fluoridation is shown by those teeth generally less subject to caries attack; the permanent molars show an 18 per cent lower DMF experience rate, and the incisor teeth a 55 per cent lower rate in Newburgh than in Kingston. Another five years will be required to present a final report.

Wallace & Tiernan Novadel-Agene Chemical Feeder at Newburgh, N.Y.

Pediatric findings in the same project were reported[11] to show no deleterious effect of fluoride intake. The same pediatric team has continuously studied 500 children in Newburgh and the same number in Kingston. By means of physical examinations, laboratory tests, bone X-ray studies, and special examinations no detectable differences can be found between the children in these two cities.

Sheboygan, Wis.: The Director of the Division of Dental Education, State Board of Health, has reported[12] on the third post-fluoridation survey at Sheboygan, where fluoridation was started in February, 1946. His survey shows that, in less than three years, the DMF rate for kindergarten children (5 to 6 years) has been reduced 28 per cent. The DMF rate for fourth grade children (9 to 10 years) has been reduced 19 per cent. In the opinion of the Wisconsin State Board of Health, the evidence presented demonstrates that artificial fluoridation of a public water supply has reduced caries about 20 per cent.

Leadership in Wisconsin

Special comment should be made concerning the growth of water fluoridation in the State of Wisconsin, where 3 municipal supplies are now treated on an experimental basis, and 5 on an empirical basis. As of August, 1949, approval had been given by the State Dept. of Health to 4 more installations, and four others have been submitted to the Department for consideration. The State Supervisor of Dental Education reported that, in addition to the above, ordinances for the fluoridation of water have been approved by 33 municipalities and have been introduced, but not yet voted upon, by 16 municipalities.

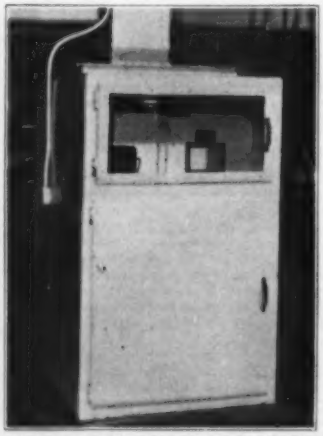
As early as 1945 the Wisconsin State Dental Society adopted a recommendation approving fluoridation of water supplies deficient in fluorides, providing that the application be under the supervision of dental, medical, engineering and public health personnel. After considerable study this action was approved by the State Board of Health in 1946. The policy of the Board was modified in 1949 so as to accept empirical installations of fluordination. The State Dental Society has a very active committee on the fluoridation of water which gives much time and effort to educational discussions before civic groups. This committee has been largely responsible for local demands that the public water supply be fluoridated. The favorable attitude of state health officials has, of course, been essential.

Fluoridation Chemicals

The fluoridation of nearly all water supplies is accomplished by the carefully regulated application of sodium fluoride. The commercial salt, having a sodium fluoride content of 90 per cent, is generally employed. The composition of this salt is such that 20.4 lb. per mil. gal. are required to apply 1.0 ppm. fluoride ion. Since many natural waters contain some fluoride ion, the amount applied must represent the difference between the concentration originally present and the concentration desired in the finished water.

One water supply employs 60 per cent hydrofluoric acid as the source of fluoride ion. The liquid is applied from storage tanks at several unit wells by means of special chemical feed pumps.

Consideration has recently been given to the use of sodium silico-fluoride instead of sodium fluoride to supply the fluoride ion. The silico-fluoride (Na_2SiF_6) contains 60 per cent fluoride ion, while the fluoride (NaF) contains 45 per cent. The prices of these compounds are such that sodium silicofluoride will supply fluoride ion at about one-fourth the cost of obtaining it from sodium fluoride. Sodium silico-fluoride is a by-product from the manufacture of phosphates from certain phosphat rocks. Its solubility is low (4.7 grams per liter at 2°C) and may be a disadvantage in this application, but should present no difficulty where the material is applied through dry feed equipment which is provided with adequate dissolving facilities. The low solubility may create a storage and feeding problem where



First Dry Feeding Installation for Sodium Fluoride in U.S.A.
(Omega Gravimetric Feeder)

solution feeders are employed. Studies of the suitability of this compound should include determination of its toxicity by means of animal feeding experiments.

M. Starr Nichols, Prof. of Sanitary Chemistry, University of Wisconsin, evaluated related technical data and concluded: "From all evidence available to me, it seems chemically and physiologically sound to use sodium fluosilicate as a carrier of the fluoride ion in the supplementation of fluoride-deficient waters." He points out that many of the igneous rocks (siliceous in nature) contain fluorides, probably as fluosilicates. Colorado Springs, Colo., obtains its water from the run-off of the Rocky Mountains. These mountains are of igneous origin and the water supply of the city contains 2.6 ppm. fluorides. We do not know, but can surmise, the natural fluoride content of many waters may result from the dissolving of fluosilicates.

His data show both sodium fluoride and sodium fluosilicate to produce mottled enamel of equal intensity (on the teeth of rats) when the intake of each substance provided an equivalent amount of fluoride ion. Investigators report sodium fluoride and sodium fluosilicate to have equal toxicities when the tolerated dose and lethal dose is determined on the basis of fluoride ion concentration.

Milwaukee was first reported to be considering the use of sodium silicofluoride as a substitute for sodium fluoride. It was estimated that water fluoridation would cost about 2.75 cents per capita per year with silico-fluoride as against 14 cents with the fluoride salt. The first plant scale study of sodium silico-fluoride appears to be that at the Sheboygan, Wisc., plant. Rhinelander, Wisc., is proposing the use of hydrofluosilicic acid, to be applied by means of chemical feed pumps.

Fluoridation Equipment

Sodium fluoride, or any fluoride salt, must be applied by means of accurate feeding equipment. Either gravimetric or volumetric dry-feed equipment, or positive displacement liquid-feed equipment having an accuracy of 5 per cent is required. The most suitable type of equipment will probably be determined by the weight of chemical to be applied per hour or per day.

Special precautions must be taken to protect the operators from inhaling fluoride dust when charging the hoppers of dry-feed equipment. It is recommended that the hoppers be equipped with dust collectors which include bag filters, operate under positive aid pressure, and are vented to the atmosphere outside the plant. Each operator who handles fluoride should be provided with his individual toxic-dust respirator and use it only when handling that chemical. When liquid-feed equipment is used, at least two solution tanks must be available for the preparation and storage of the fluoride solution.

Equipment suitable for feeding sodium fluoride may be obtained from the following manufacturers and perhaps others:

Gravimetric loss-in-weight and volumetric types of feeders with dust collecting equipment—Omega Machine Co., Providence, R.I.; Wallace & Tiernan Co., Inc., Newark, N.J.

Volumetric types of feeders with dust collecting equipment—Infilco, Inc., Chicago, Ill.

Positive displacement types of liquid feeders (diaphragm types)—Proportioneers, Inc., Providence, R.I.; Wallace & Tiernan Co., Inc., Newark, N.J.

Positive displacement types of liquid feeders (plunger types)—Proportioneers, Inc., Providence, R.I.

Other types of liquid feeders: Decanting type—Liquid Conditioning Corp., Philadelphia, Pa.; Constant-head orifice type—Infilco, Inc., Chicago, Ill.; Wet chemical type—The Permutit Co., New York, N.Y.

Equipment suitable for feeding 60 per cent hydrofluoric acid may be obtained from the following manufacturer and perhaps others: Fluid plunger types of chemical feed pumps—Proportioneers, Inc., Providence, R.I.

Financing Fluoridation

It is obvious that the fluoridation of a water supply will increase the utility's operating expense and investment cost. The total cost is estimated to range from 5 to 15 cents per capita yer year, depending upon the amount of fluoride in the supply before fluoridation, the size of the community and the per capita use of water. The cost of fluoridation may be considered a proper charge against communal health activities since the benefits to be derived by consumer bear no relation to the amount of water used. This method of financing is probably that most widely employed to date.

However, the laws of the state of Wisconsin relating to water charges were amended during 1949 to read:

"The council or board of any town, village or city operating a public utility may, by ordinance, fix the initial rates and provide for this collection monthly, quarterly, or semiannually in advance or otherwise. The rates shall be uniform for like service in all parts of the municipality *and shall include the cost of fluorinating the water*. The charges shall be collected by the treasurer."

"In the case of a public water utility, the commission shall include, in the determination of water rates, the cost of fluorinating

the water in the area served by such public water utility, provided the local governing legislative body in which such public water utility is situated authorizes the fluorination of water in the area primarily served by such public water utility."

The Topical Application of Fluoride

A relatively simple technique has been developed—for the dental profession to apply dilute sodium fluoride solution directly to teeth. This method of treatment is termed a "topical application" and has been studied for more than five years. Each treatment involves four visits to the dentist, but the technique is simple: The first treatment consists of cleaning the teeth and wetting them with sodium fluoride solution; the second, third, and fourth treatments require only the application of sodium fluoride solution. This treatment has been shown to effect a 40 per cent reduction in dental caries. The effect lasts from 3 to 5 years, and it is suggested that the topical application be repeated at ages 3, 7, 10 and 13.

Needed Research

Further experimental studies are necessary to determine the effect of climate and geopraphical location as factors in water fluoridation. The A.W.W.A. statement of policy discusses evidence that a constant and uniform fluoride content of 1.0 ppm. may be inadequate, where water consumption is low, and fail to exert the maximum protective effect; or may be excessive, where water consumption is high and result in the formation of mottled enamel. A recent report indicates that in one community in New Mexico fluorosis may result from the presence of as little as 0.7 ppm. in the water supply. It has been suggested[13] that the technic of fluoridation be refined on a seasonal basis for each installation; by this method the fluoride concentration would be varied in relation to the temperature of the locality (and hence the water intake) so as to receive the maximum protection from caries and the minimum development of mottled enamel.

It is reported that that free available residual chlorine interferes with the test for fluoride as given in the latest edition of "Standard Methods for the Examination of Water and Sewage," and a satisfactory method for the elimination of errors due to such interferences must be developed.

The fluoridation of one water supply appeared to result in a serious increase of cracking in ice manufactured from the water. This problem is reported to occur in no other municipality practicing fluoridation and may be due to the exceptionally low dissolved solids content (45 ppm.) of the particular water supply.

A Summary of Opinion

There exists little or no question as to the desirability of adding fluoride in the several full scale *control* studies now under way in several municipal water supplies. These may be considered careful experimental studies, and the results will be very significant. The present question, difficult to answer, concerns the general application of fluoride to any water supply deficient in this constituent. The terminology employed often reflects the point of view of those discussing the problem. The addition of fluoride has been termed mass medication; more favorably, it has been considered supplemental treatment; or, even more attractively, it has been labeled enrichment of the water supply.

No program thus far suggested for the reduction of tooth decay, except the use of waters naturally containing fluoride, has succeeded in delivering any considerable proportion of a mass population into adult life with an average caries experience rate of about three per person and with a complete absence of decay in approximately one-third of a native population. The problem of tooth decay is a serious one—both from public health and economic considerations.

It is true that excessive fluoride concentrations in water can cause mottled enamel, and some communities using such waters should employ methods for the removal of naturally present fluoride concentrations. It is equally true that the application of fluoride to a public water supply for the reduction of dental decay should not prove a difficult problem. Many supplies are now being treated for clarification, taste and odor control, disinfection, softening, stability, etc., so that chemical feeding equipment and control measures are well established and widely used.

Much of the personnel now responsible for water quality is highly trained. It is obvious, therefore, that should a program for applying fluoride be undertaken, those supplies now receiving treatment under local laboratory control would have no difficulty in applying an additional chemical. Most of these supplies would require only suitable chemical feed equipment to adopt fluoride treatment.

Even though the benefits of the treatment are evident from a public health and financial viewpoint, it is still prudent to consider the legal responsibilities that a community or private utility accepts when it establishes the fluoride treatment of a public water supply. An answer to this question is provided by Faust of the Michigan Department of Health. The opinion of the Attorney General of that State is cited to show that, legally, there is no change in the responsibility of the water utility which applies fluoride to a water supply. Negligence in treatment which results in damage must be shown to establish liability. There would be no method by which a consumer not injured by, but not sympathetic to, the program of fluoride treatment, could prevent such treatment.

There would appear to be no conflict between the fluoride treatment of a public water supply and any individual treatment for the prevention of dental caries. If both the treatment of water supplies and the topical application of fluoride to the teeth were employed, there would be ample need for all the conventional facilities in the form of dental service which can be provided. The studies of the Committee on the Costs of Medical Care of the A.P.H.A. showed that in 1929—at the peak of peacetime prosperity—the individual in the lower half of the population from an economic standpoint had, on the average, one-tenth of a visit to a dentist per year.

An excellent example of an educational program is that of the city of Sheboygan, Wisconsin, where water department officials assisted in assembling and collecting facts for and against the adoption of fluoridation. The publicity resulted in approval by county medical and dental societies, by the state dental society, and by the City Board of Health. After several sessions of discussion an ordinance was passed by the Common Council. It authorized and directed the City Dept. of Public Health, upon approval of the State Board of Health, to proceed with fluoride treatment, using the facilities of the Water Dept.; the cost to be paid out of the general fund of the city. The State Board of Health approved, and its Bureau of Sanitary Engineering has assisted in fluoridation at Sheboygan. The treatment was started in February, 1946.

It has been stated, with good reason, that the results of "experiment" or controlled studies, at those communities now adding fluoride to their water supplies, will be little more conclusive than the mass of data on those waters naturally containing approximately 1.0 ppm. fluoride. These data have been accumulated during the past fifty years and have been carefully evaluated. There is little doubt that artificially applied fluoride (or mass medication, or supplemental treatment, or enrichment of the water supply) will have an effect differing from that of fluoride naturally present.

Now, while waiting for a little additional data (the results from those communities where fluoride is applied) to be accumulated, a generation of children will grow up with a high rate of tooth decay. After that time, no preventive treatment can be applied to their teeth. It is on this basis that the city of Madison, Wis., decided to employ fluoride treatment while awaiting the results of those controlled studies already under way[12]. The local authorities considered no other method contemplated to be so safe, so adequate, and so economical.

This method of treatment was considered *safe* because not enough water containing 1.0 ppm. fluoride could be consumed to cause the least harmful effect. It was considered *adequate* because every child, regardless of social, economic, or educational status, would be able to benefit without effort on the part of his parents. And this method was considered *economical* because it costs only about ten cents per capita per year.

Shall fluoride be added to public water supplies? The answer to this problem will be supplied in part by the results of controlled studies now under way, in part by the results of any other known preventive methods, or future discoveries, and in part by local considerations. Do the potential benefits of reducing the incidence of tooth decay warrant a new concept of water treatment for immediate adoption?

Acknowledgment

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RECOMMENDED POLICY AND PROCEDURE FOR THE FLUORIDATION OF PUBLIC WATER SUPPLIES*

Statement Approved by the AWWA Board of Directors

Special Committee on Fluoridation Policy; A. P. Black, Chairman

In communities where a strong public demand has developed and the procedure has the full approval of the local Medical and Dental Societies, the Local and State Health Authorities, and others responsible for the communal health, water departments or companies may properly participate in a program of fluoridation of public water supplies.

The results of several carefully conducted epidemiological studies on the relationship between fluoride occurring naturally in communal water supplies and the prevalence of dental caries have demonstrated that the presence of 1-1.5 ppm. of fluoride (F) in drinking water is associated with a 50-65 per cent reduction in caries prevalence. The discovery of this phenomenon engendered the proposal that fluorided be added to communal water supplies as a caries prophylactic measure. This proposal is now being tested in several communities in the United States. A preliminary indication of the full effect of artificially fluoridated drinking water on dental caries will not be forthcoming, however, until children in the test areas have used such waters throughout the enamelification period of the teeth—birth through age eight years for all teeth except third permanent molars.

The water industry is being confronted with demands for the addition of fluorides to water supplies and many utility managements need assistance in handling such demands. Although available evidence supports the hypothesis that fluoridated water will be an effective caries preventative, the evidence is presumptive. It should be remembered, however, that all epidemiological evidence is presumptive. The value of presumptive evidence depends directly upon the amount and kind of scientific data submitted in support or refutation of the hypothesis advanced.

The water supply industry has always been progressive in matters pertaining to public health and welfare. It has initiated extensive research on subjects pertaining to water quality and has been prompt to adopt new processes and techniques when these have been found to improve the quality of public water supplies. It has cooperated closely with public health agencies. The problem of caries control by the fluoridation of public water supplies has not followed the old patterns which have led to past changes and improvements in water supplies. Whereas public health agencies and the water works industry have generally agreed upon the changes to be made to produce better community health, the present demands for the fluoridation of water supplies are coming from the public and the press in advance of any final decision among public health authorities that artificial fluoridation will be effective against dental caries. The water works industry recognizes these demands of the public it serves and wishes to cooperate with civic and public health authorities, from whom it must receive direction, in the solution of the problem of reducing dental caries.

Lines of Action

The policy and procedure with respect to the fluoridation of public water supplies may, in the light of present knowledge, be broadly divided into two categories: experimental and empirical.

1. *Experimental.* In certain communities the fluoride-dental caries hypothesis is being subjected to experimental verification under acceptable scientific methodology. This procedure obviously necessitates the use of a nearby "control" city with a water supply comparable in all respects to that to which fluoride is being added. The personnel engaged in such studies should include trained dental examiners, epidemiologists, biostatisticians, analytical water chemists, biochemists and other specialists who may contribute to the more complete delineation of the experiment. Examples of this type of study are Grand Rapids, Mich.; Newburgh, N.Y.; Brantford, Ont., and Evanston, Ill.

One of the factors which further experimental studies may be expected to reveal is what might be termed the climatological or geographical factor. It would be highly desirable to have a number of additional fluoridation studies in different states. These experiments should be so distributed geographically as to provide specific information on the optimal concentration of fluoride needed under particular climatological conditions. It is quite possible that more than 1 ppm. might be required in areas having a low mean annual temperature, such as the Dakotas, while 0.5-0.6 ppm. might suffice where climatological conditions are reversed, as in the deep South or the Southwest.

Additional controlled fluoridation studies, properly distributed geographically, would give direct proof on such points as: [1] the effectiveness of fluoride, [2] the optimal fluoride concentration for different geographical areas and [3] the possible influence, on the fluoride potency, of other chemical constituents of natural waters, insofar as these and other variables may affect the action of fluoride on the control of caries in a human population.

2. *Empirical.* An ever increasing number of communities are willing to provide the cost of fluoridation for the purpose of giving anticipated protection to the oncoming generation of children at the earliest possible time, while awaiting the outcome of controlled experiments.

Although it would probably be desirable from a sound scientific standpoint to await the results of the controlled experiments, the large amount of epidemiological evidence poses an ethical question. This has been well stated by Enslow: "If the process proves worthy of adoption sometime hence, a community denied fluoridation during any period of 'watchful waiting' will have lost the value of the treatment for such period. Neither is it pleasant to contemplate that such loss in tooth protection amongst the youngsters cannot be made up through subsequent water treatment." [From an editorial in Water & Sewage Works.]

Policy

In communities where a strong public demand has developed and the procedure has the full approval of the local medical and dental societies, the local and state health authorities, and others responsible for the communal health, the water departments or companies may properly participate in a program of fluoridation of the public water supplies.

Tentative Recommended Procedure

Recognizing that water fluoridation is still in the experimental stage, it appears desirable to include as part of this report a statement of recommended procedure which may be helpful from a practical point of view.

Sec. 1—Handling Fluoridation Requests

1.1. All requests that fluoride be added to the water supply for the reduction of the incidence of dental caries, which is a public health matter, should be referred to the state (or provincial) and local public health authority.

1.2. The water utility is charged with supplying water meeting standards adopted by the controlling health authority. With regard to fluoride, a maximum concentration of 1.5 ppm. of fluoride ion may be permissible.

Sec. 2—Responsibility for Fluoridation

Any decision to add fluoride to a water supply should be concurred in by the following authorities and agencies before there is any commitment by the water utility: the local health department, the state or provincial department of health, the local dentists or dental society, the local medical society and the local municipal governing body, board or council. The approval of the state or provincial public utility commission may also be necessary if the utility is privately owned. A ruling should be obtained from the state attorney general; obviously only one such ruling will be required for each state.

Sec. 3—Liability Involved

3.1. The water utility may be liable for damages caused by the fluoridation of a water supply when such chemical is added without specific authorization from controlling health agencies.

3.2. The water utility may be liable for damages caused by negligence in the application or control of the fluoride. The application of insufficient, as well as too much, fluoride might be construed as negligence.

Sec. 4—Steps in Authorization

The operating management of a water supply utility should begin the addition of fluoride in the water supply only after:

4.1. The governing body of the municipality has authorized fluoridation by ordinance, and the local and state health authorities have approved the addition of fluoride and have: [1] established reasonable maximum and minimum limits of fluoride, stated in parts per million, to be maintained in the water supply; [2] approved the type of chemical feeding equipment to be installed and used; [3] approved the installation of equipment, plant layout and methods of handling the fluoride compound to assure the safety of employees; and [4] approved the method of analysis and control to be used in determining the fluoride content of the water before and after the addition of fluoride.

4.2. The state or provincial public utility commission has released, when required, any necessary orders—for example, a method by which the utility will be reimbused for the expense of fluoridation.

4.3. The legal counsel of the water department or company has made a finding that all necessary authorization has been given to the water utility so that legal

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liability for damages will be limited to negligence.

4.4. The board of directors or similar governing body of the utility has, by resolution, instructed its proper operating officers and employees to add fluoride as specifically authorized by the controlling health and municipal authorities.

Sec. 5—Disposition of Cost

5.1. The fluoridation of a water supply will increase the utility's operating expense and investment cost. The total cost will probably range from 5 to 15c per capita per year, depending upon the amount of fluorde in the supply before fluoridation, the size of the community and the per capita use of water.

5.2. The method by which the cost of fluoridation will be defrayed should be determined before the water utility agrees to the treatment.

5.3. When any authority, such as a public utility commission, has jurisdiction over accounting procedures and water rate charges, the necessary order from such authority should be obtained.

5.4. The cost of fluoridation should not be charged to the cost of water works operation, since the benefits to be derived by the consumer bear no relation to the amount of water used. Although the methods of assessing these charges upon the consumer will vary with the individual utility, the idea should be kept in mind that the cost of fluoridation is a proper charge against communal health activities.

Sec. 6—Items of Cost

6.1. *Investment costs.* The probable facilities and equipment required to add fluoride are: [1] feeding equipment and [2] storage room. (This room may have to be separate from the storage space used for other chemicals, particularly if containers are opened in the room, because of the toxic nature of the chemical. Special ventilating equipment may be required.)

6.2. *Operating costs.* The several operating costs are:

1. Cost of the fluoride, including freight
2. Handling labor or stores costs
3. Operating labor costs
4. Equipment maintenance costs
5. Laboratory control costs
6. Additional insurance costs, if the legal counsel of the water utility finds that the fluoridation of the water supply may subject employees to occupational disease hazards and the utility to possible damage suits.
7. Investment overhead costs: [1] depreciation expense on structures and equipment; [2] interest or return on investment; and [3] taxes, if any, on the assessed value of structures and equipment.

Sec. 7—Application of Fluoride

7.1. The application of fluoride must be made through accurate feeding equipment. Either gravimetric or volumetric dry-feed equipment or positive-displacement liquid-feed equipment with an accuracy within 5 per cent is required.

7.2. Special precautions must be taken to protect the operators from inhaling fluoride dust when charging the hoppers of the feeders. It is recommended that dry feeders be equipped with dust collectors consisting of bag filters operating under positive air pressure and vented to the outside. Each operator who handles fluoride should be provided with his individual toxic-dust respirator to be used only when handling the chemical. When liquid-feed equipment is used, at least two solution tanks must be available for the preparation and storage of the fluoride solution.

Sec. 8—Control

8.1. Laboratory analysis and control should follow specific instructions from the controlling health authority.

8.2. Samples must be taken from points before and after fluoridation and from one or more points in the distribution system, as determined by the controlling health authority. The frequency of sampling shall be determined by the controlling health authority.

8.3. The method of determining the fluoride content of the water shall be specified by the controlling health authority and shall be in agreement with the latest edition of *Standard Methods for the Examination of Water and Sewage.*

8.4. The results of all chemical tests shall be recorded on forms approved by the controlling health authority and by the legal counsel of the water utility. Water samples for chemical analysis shall be submitted to the state health authority at stated intervals for control purposes.

8.5. The tests for the purity of the fluoride chemical used in water fluoridation shall have the approval of the state health authority. These tests shall include the U.S. Pharmacopoeia tests for heavy metals (U.S. Pharmacopoeia, XII, page 720).

The Committee

A. P. Black, Chmn.

A. E. Berry — H. A. Faber
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L. H. Enslow — W. V. Weir

Cost of Water at Stated Rates per 1,000 Gallons

Cubic Feet	U. S. Gallons	COST PER 1,000 GALLONS						
		6 Cents	8 Cents	10 Cents	15 Cents	20 Cents	25 Cents	30 Cents
20	150	$ 0.009	$ 0.012	$ 0.015	$ 0.022	$ 0.030	$ 0.037	$ 0.045
40	299	0.018	0.024	0.030	0.045	0.060	0.075	0.090
60	449	0.027	0.036	0.045	0.066	0.090	0.112	0.135
80	598	0.036	0.048	0.060	0.090	0.120	0.150	0.180
100	748	0.045	0.060	0.075	0.112	0.150	0.187	0.224
200	1,496	0.090	0.120	0.150	0.225	0.299	0.374	0.449
300	2,244	0.135	0.180	0.224	0.336	0.449	0.561	0.673
400	2,992	0.180	0.239	0.299	0.450	0.598	0.748	0.898
500	3,740	0.224	0.299	0.374	0.561	0.748	0.935	1.122
600	4,488	0.269	0.359	0.449	0.673	0.898	1.122	1.346
700	5,236	0.314	0.419	0.524	0.786	1.047	1.309	1.571
800	5,984	0.359	0.479	0.598	0.897	1.197	1.496	1.795
900	6,732	0.404	0.539	0.673	1.010	1.346	1.683	2.020
1,000	7,480	0.449	0.598	0.748	1.122	1.496	1.870	2.244
2,000	14,961	0.898	1.197	1.496	2.244	2.992	3.740	4.488
3,000	22,441	1.346	1.795	2.244	3.366	4.488	5.610	6.732
4,000	29,922	1.795	2.393	2.992	4.488	5.984	7.480	8.976
5,000	37,402	2.244	2.992	3.740	5.610	7.480	9.350	11.220
6,000	44,883	2.692	3.590	4.488	6.732	8.976	11.220	13.464
7,000	52,364	3.141	4.189	5.236	7.854	10.472	13.090	15.708
8,000	59,844	3.590	4.787	5.984	8.976	11.968	14.961	17.953
9,000	67,325	4.039	5.385	6.732	10.098	13.464	16.831	20.197
10,000	74,805	4.488	5.984	7.480	11.220	14.961	18.701	22.441
20,000	149,610	8.976	11.968	14.961	22.442	29.922	37.402	44.882
30,000	224,416	13.46	17.95	22.44	33.662	44.88	56.10	67.32
40,000	299,221	17.95	23.94	29.92	44.883	59.84	74.80	89.77
50,000	374,026	22.44	29.92	37.40	56.104	74.80	93.50	112.20
60,000	448,831	26.92	35.90	44.88	67.325	89.76	112.20	134.64
70,000	523,636	31.41	41.89	52.36	78.546	104.72	130.90	157.08
80,000	598,441	35.90	47.87	59.84	89.766	119.68	149.61	179.53
90,000	673,247	40.39	53.85	67.32	100.986	134.64	168.31	201.97
100,000	748,052	44.88	59.84	74.80	112.21	149.61	187.01	224.41
200,000	1,496,104	89.76	119.68	149.61	224.42	299.22	374.02	448.82
300,000	2,244,156	134.64	179.53	224.41	336.62	448.83	561 03	673.24
400,000	2,992,208	179.53	239.37	299.22	448.83	598.44	748.05	897.66
500,000	3,740,259	224.41	299.22	374.02	561.04	748.05	935.06	1122.07
600,000	4,488,311	269.29	359.06	448.83	673.25	897.66	1122.07	1346.49
700,000	5,236,363	314.18	418.90	523.63	785.45	1047.27	1309.08	1570.91
800,000	5,984,415	359.06	478.75	598.44	897.66	1196.88	1496.10	1795.32
900,000	6,732,467	403.94	538.59	673.24	1009.87	1346.49	1683.11	2019.73
1,000,000	7,480,519	448.83	598.44	748.05	1122.08	1496.10	1870.12	2244.15

THE HYDRAULIC PUMPING RAM*

THE increased development of certain rural areas for farming and other purposes has introduced many urgent problems of water supply for which effective and economical solutions have been found in the use of the Hydraulic Pumping Ram, a machine which can be manufactured quickly and installed with the minimum of constructional work.

The hydraulic ram will work efficiently on any fall of water of 3 feet or more, up to about 80 feet, and will elevate water up to 300 feet. For the highest delivery heads however, a working fall of at least 12 feet is necessary. The following expression is useful:—

$$q = \frac{QH}{h}\eta$$

Where q = water raised, g.p.m.

h = height water is raised above ram, feet.

Q = flow of water used by ram, g.p.m.

H = working fall, feet.

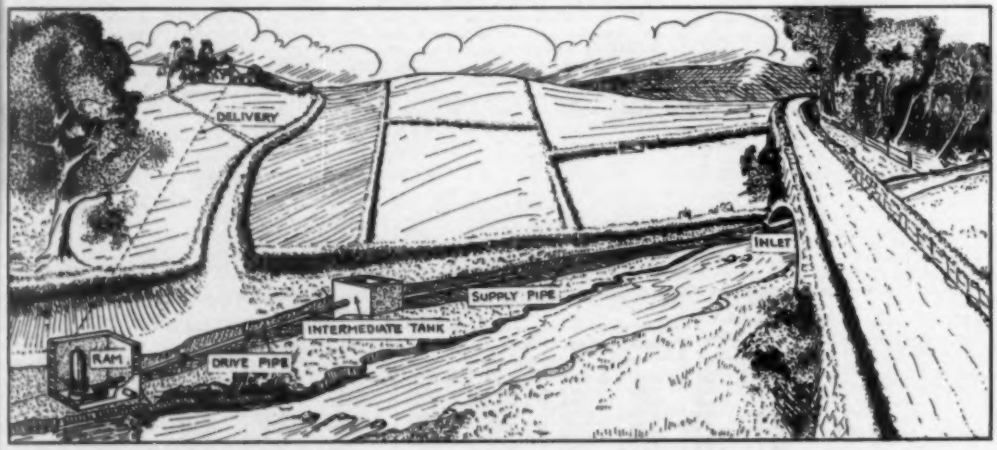
η = efficiency. (Average value for rough calculations 0.6).

Efficiency varies with the different factors, particularly with the ratio of the length of the drive pipe to the working fall H, and falls off if ratio of delivery to supply head becomes very great. It is recommended that the ratio of the length of the drive pipe to the working fall be made not much more than 6, with a minimum length of drive pipe of about 60 feet. But there is no hard and fast rule about this, and many rams are working satisfactorily with ratios much greater than 6 and with drive pipes much shorter than 60 feet.

The working head can be obtained in various ways. If a water fall exists in a stream, or if two water sources are available at different levels, an inlet can be made at the high level and a drive pipe of suitable length laid directly to the ram situated at the low level. If, on the other hand, the hydraulic gradient of a stream is to be utilized, a fall can be developed in the manner shown in the sketch above, in which a feed pipe is taken from an inlet to an intermediate chamber built up to the same level as the inlet, and from this chamber a drive pipe laid to the ram. It is very desirable in all cases that the drive pipe, which must be of flanged cast-iron or screwed steel piping, be laid in a straight line with uniform gradient. The supply pipe to the intermediate chamber and the rising main can be laid to follow the contours of the ground, although peaks should be avoided, as there is risk of air collecting and impeding flow. If a peak cannot be avoided an air valve should be fitted at the highest point. No peak may rise above the hydraulic gradient.

The hydraulic ram can be "simple" or "compound." The "simple" ram lifts part of the water used to drive it, the "compound" machine is operated by one source, as from a stream, and lifts water from another source, as from a spring. Direct contamination of the spring water by the stream water is avoided.

*From the *Glenfield Gazette*—A Journal of Hydraulic Engineering; Glenfield and Kennedy, Ltd., Kilmarnock, Scotland.



Typical Layout of Hydraulic Pumping Ram, When Slope of Stream is to be Developed to Provide a Working Head

Decimal Equivalents
of 8ths, 16ths, 32ds, and 64ths of an Inch

8ths				
1/8 = .125	9/16 = .5625	17/32 = .53125	9/64 = .140625	37/64 = .578125
1/4 = .250	11/16 = .6875	19/32 = .59375	11/64 = .171875	39/64 = .609375
3/8 = .375	13/16 = .8125	21/32 = .65625	13/64 = .203125	41/64 = .640625
1/2 = .500	15/16 = .9375	23/32 = .71875	15/64 = .234375	43/64 = .671875
5/8 = .625		25/32 = .78125	17/64 = .265625	45/64 = .703125
3/4 = .750	32ds	27/32 = .84375	19/64 = .296875	47/64 = .734375
7/8 = .875	1/32 = .03125	29/32 = .90625	21/64 = .328125	49/64 = .765625
	3/32 = .09375	31/32 = .96875	23/64 = .359375	51/64 = .796875
16ths	5/32 = .15625		25/64 = .390625	53/64 = .828125
1/16 = .0625	7/32 = .21875	64ths	27/64 = .421875	55/64 = .859375
3/16 = .1875	9/32 = .28125	1/64 = .015625	29/64 = .453125	57/64 = .890625
5/16 = .3125	11/32 = .34375	3/64 = .046875	31/64 = .484375	59/64 = .921875
7/16 = .4375	13/32 = .40625	5/64 = .078125	33/64 = .515625	61/64 = .953125
	15/32 = .46875	7/64 = .109375	35/64 = .546875	63/64 = .984375

FUNDAMENTALS OF CORROSION AND ITS MITIGATION*

E. W. MOORE[1], W. H. SEARS[2], AND L. RUBIN[3]
NEWWA Committee on Corrosion

THE Committee to Report on Developments in our Knowledge of Corrosion and its Mitigation was established by the N.E.W.W.A. in 1942. The pressure of war activities on the membership of the Committee prevented any effective work during the subsequent years until July, 1948, when a meeting was held to determine its future course.

Further discussion led to the conclusion that the Committee might partially fulfill both objectives by adopting the following courses of action:

1. To prepare a basic report which would, insofar as possible, summarize present knowledge on corrosion.

2. Using this basic report as a point of departure, to examine critically the new developments in the field at such times as the Committee considers that sufficient evidence is at hand for examination and reporting.

The present report is submitted as the basic report of the Committee.

I. Definition of Corrosion

In order to carry on adequate studies of corrosion in the field of water supply, it is necessary that criteria be established that may be used to determine the existence and the extent of the problem. Since corrosion has to do with piping systems and water supplies, its existence is recognized by its effects on either or both. In general, the effects of corrosion on the water supply are manifested much sooner than the effects on the piping system. This report will deal primarily with the corrosion of the interior surfaces of piping and will not be concerned, except indirectly, with corrosion of the exterior surfaces due to contact with various types of soils or to other agencies.

1. **Effect on System—Destruction, Tuberculation, Clogging.** Corrosion consists primarily of the solution of the metal components of the piping system by the action of the various substances present in water. The continuous solvent action results in a weakening of the pipe structure, which eventually may manifest itself in many ways, such as

a. Leaks in service lines, mains, domestic piping
b. Leaks in domestic hot water boilers
c. Corrosion of water meter parts

Inspection of any piping that has developed a leak will reveal the solvent effect of corrosive action in the form of pitting, dezincification, or general reduction in pipe thickness.

Another evidence of corrosion is the occurrence of tuberculation in the piping. When certain metals, especially iron, go into solution in water, they tend to react with the basic substances and the dissolved oxygen in the water and form insoluble compounds. These compounds tend to form and adhere to the pipe in the immediate vicinity of the point where the corrosion is taking place. This precipitate adheres to the pipe and accumulates in the form of tubercles. The effect of such tuberculation is to reduce the carrying capacity by a decrease in the effective diameter of the pipe and by an increase in the frictional resistance to flow. Where tuberculation is excessive, marked reduction of flow and pressure will occur, and reduction in flow and pressure in sections of a water supply system may be taken as evidence of marked corrosion of the piping system.

2. **Effect on Water.** When corrosion of piping occurs, the metal goes into solution in the water in the form of charged atoms, which are called ions, and therefore the presence of these corrosion products in the water is evidence of the existence of corrosion.

a. *Soluble and Insoluble Metallic Compounds*

The presence of some metal ions in water may be evidenced by visible effects such as the presence of sediment, by an increase in the turbidity of the water, by a change in the color, or by the imparting of a visible coloration to an otherwise satisfactory, colorless water.

b. *Turbidity, Color*

Where iron pipe undergoes corrosion, iron hydroxide is formed, which is usually manifested in the familiar form of brown iron rust, somewhat fluffy in appearance. Occasionally during a heavy draft on the pipe or a change in the direction of flow, a certain amount of the tuberculation of iron hydroxide will be loosened from the main and appear in the tap water as a brownish sediment. Small quantities of iron in solution in a water will impart a turbidity or a yellowish color to the water because of the presence of iron in colloidal form. The presence of high concentrations of copper in solution will impart a bluish cast to the water. Such concentrations are rather unusual in water supplies, but the addition of soap to the water or the presence of a large volume of water, as in a bathtub, will tend to bring out the bluish color. The presence of zinc or lead rarely imparts either color or turbidity to a water.

c. *Taste*

High concentrations of metallic ions will impart a characteristic unpleasant metallic taste to the water. For instance, iron in solution imparts a sharp metallic taste in concentrations of approximately 0.5 to 2.0 ppm.; copper is similarly perceptible in concentrations of about 5 to 10 ppm., and zinc in concentrations of about 20 ppm.

d. *Toxicity*

The presence of metallic ions in water may sometimes affect the health of the consumer. Of the various metals commonly found in water supplies, lead is the most harmful. Concentrations in excess of 0.1 ppm. are considered unsafe for potable supplies. Although there is little or no evidence of damage to health from the presence of either copper or zinc in concentrations such as occur in water supplies, it has been found desirable to limit the concentration of copper to a maximum of 3.0 ppm. and of zinc to 15 ppm. in potable waters. There is no evidence of any physiological effect produced by excessive amounts of iron in solution, but its presence is objectionable for various domestic purposes in concentrations of over 0.3 ppm.

B. Quantitative Estimation of Corrosion

1. **Methods Available for Measuring Corrosion.** Measurement of the extent of corrosion consists in determining either the extent of its action on the metallic piping, its effects on the water stored in the pipes, or both.

Quantitative measurement of the extent of corrosion of the piping system may be based on any of the following methods:

a. Loss of weight of the metal
b. Depth of pitting of the metal in a given time interval
c. Change in the friction coefficient of the pipe
d. Frequency of required meter overhaul and of incidence of failure of domestic plumbing fixtures such as hot water boilers

The first two methods are of value in the determination of the relative corrodibility of various metals and as a guide in the choice of the best metal for a given purpose. The extent of the penetration of a metal due to corrosive action in a given interval of time may be used in gaging the probable useful life of the metal, and comparison of these effects on two or more metals under the same conditions of corrosion may be used to estimate the relative merit of such metals. These methods are of relatively little use in the waterworks field, first, because most corrosion problems are concerned with old piping systems, and, second, because where the choice of new piping is involved the time required to carry out such measurements is usually not available. Once a piping system is installed there is rarely an opportunity to remove sections for study of corrosion effects.

In this connection it may be stated that the so-called "jar test"*—in which a small section of pipe is allowed to stand in contact with a fixed quantity of water for a certain interval of time and the results observed, usually visually—is not a satisfactory method for predicting the results that will be obtained in actual use. The rapid change in the corrosive properties of the water and the unusual initial corrosion effects on the metal make the jar test of little value.

The tuberculation caused by corrosive action offers a satisfactory means for the quantative determination of the extent of corrosive action. The effect of tuberculation is of course to increase the friction loss through the pipe and to reduce the effective diameter of the piping. Where it is known that the tuberculation is caused primarily by corrosion, measurements for the determination of the value of "C" in the Williams and Hazen formula offer a fair criterion of the condition in the mains. However, it must be noted that some forms of pipe incrustation are not related to corrosion.

Where means for such measurements are not available, a more qualitative and less satisfactory method is to look for corroion and clogging of the meter parts and to note the interval between the required cleanings of meters. Too frequent clogging of meter

*Report of the NEWWA Committee on Developments in Our Knowledge of Corrosion and Its Mitigation. Published here by permission of the Association.

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*Not to be confused with the jar test for determining coagulation dosages.

gears indicates excessive corrosion. Similarly, unusually short life of domestic plumbing systems such as hot water boilers and house piping offers a rough indication of the extent of the corrosive effects of the water.

The change in the quality of the water between the source and the consumer's tap after passage through the various service lines offers an indirect measure of the extent of corrosion of the various kinds of metallic piping in the system. An increase in the content of iron, copper, zinc, or lead indicates corrosive action, and its intensity can be estimated by considering the increase in metal concentration with respect to the time of contact between water and pipe.

The dissolved oxygen content of the water can be used as a measure of the extent of corrosion of iron piping. Since oxygen is a primary agent in promoting corrosion and since it is used up in proportion to the amount of iron being dissolved, the drop in the dissolved oxygen content between any two points in a piping system is a measure of the extent of the corrosive action taking place there.

A far less satisfactory indication, yet one which may be of some value, is the extent of the manifestation of some of the effects of corrosion on various plumbing fixtures. For instance, numerous complaints of green stains on white porcelain fixtures is an indication of corrosion of copper or brass pipe. The presence of excessive iron in solution results in numerous complaints of brown stains on plumbing fixtures and the staining of clothes in the process of laundering.

2. **Evaluation of Anti-Corrosion Treatments.** Where steps are taken to reduce the corrosiveness of the water by chemical treatment or otherwise, it is essential that adequate data be obtained to determine the effectiveness of such treatment. As previously indicated, the effects of corrosion are manifested in various ways and after various time intervals. Whether treatment has resulted in a decrease in the corrosion, pitting, or tuberculation in the mains and service lines can be determined only after a period of several months or years. It must be borne n mind that when treatment is begun, the piping system consists of mains and service lines of various metals in varied condition with respect to corrosion. Some may already be badly pitted or tuberculated; some may be relatively free from pits or tubercles; all have coatings of corrosion products, pipe growths, or organic matter of difference densities and protective value. Therefore, when the water applied to such a system is treated to alter its corrosive properties, the manifestation of this change in corrosiveness will be varied and difficult to evaluate immediately. The longer the interval of treatment, the clearer will be the picture of the relative effectiveness of the treatment. Where the treatment has been accompanied by a program of main cleaning, or flushing, some of the immediately apparent effects may be due merely to such cleaning. Any other steps taken in conjunction with the corrosive correction treatment, such as elimination of dead ends, should also be properly evaluated in the overall picture.

In general, the change in the corrosive effects of a water on a piping system can be evaluated only after a period of possibly six months or a year, when a reduction in the frequency of the occurrence of leaks in service lines, clogging and corrosion of the meter parts, clopping of piping, or loss of water pressure at taps indicates the effectiveness of the corrosive correction treatment.

The effectiveness of the treatment first manifests itself in improvement in the condition of the water as drawn from taps throughout the systems. For this purpose it is desirable that as an aid in the determination of the improved water quality certain representative taps be chosen with respect to the type and condition of the water-supply lines of the system and samples of the water be drawn from them under standard conditions of flow for a period of time before treatment is begun. After treatment has been instituted, additional samples can be taken under the same conditions and the change, if any, in the quality of the water can be noted. Such a sampling program should be well planned as to representative samples and be carried out for a sufficient period of time before and after treatment to give a proper picture of the condition of the water. Tests for the various metal ions as well as the dissolved oxygen content will be especially valuable in this work.

3. **Relation of Measurements to Consumer Complaints.** As previously indicated corrosive action is continuously occuring when metal piping is in contact with water. The extent of the action varies with the type of piping and the character of the water supply. The point at which a water is considered sufficiently corrosive to require corrective treatment is quite dependent on the particular community concerned. The waterworks superintendent is concerned especially with corrosion of piping as a cause of leaks or breaks that require repairs, the clogging or corrosion of meter parts, and the tuberculation or clogging of mains and service lines. The consumer, on the other hand, is especially aware of corrosion as it affects the quality of the water. Thus the staining of clothes or of plumbing fixtures by iron or copper compounds is apt to cause complaints to the water department. The appearance of sediment, such as iron rust due to sloughing off of deposits in pipes, will cause considerable objection. There is usually no close relationship between the extent of the corrosive effects, the number of complaints, and the consequent public pressure to require corrective treatment of the water supply. Because of the variation in public reaction to the effects of corrosion, caution must be exercised to avoid evaluating the effects of corrosive treatment solely on the basis of consumer reaction. While the incentive for initiation of corrective treatment in many cases comes from the reaction of the consumers, consumer opinion is not too reliable an index of the effectiveness of the anticorrosion treatment. Reduction in the number of complaints about the appearance of the water and the staining of clothes and fixtures is of value in judging the effectiveness of treatment, but the chief reliance should be placed on the analytical data concerning the water at the various taps before and after treatment. In any case, a sufficient time interval should be allowed before deciding on the effectiveness of treatment, because, as has already been indicated, corrosion is a very slow process and many of its effects are not manifested until an interval of months or years has passed.

II. Fundamental Reactions of Corrosion

No metal is truly stable in the presence of moisture and oxygen, and all metals tend toward ultimate conversion to oxides, hydroxides, or salts of the metallic element, with consequent destruction of the integrity of the metal. There are some metals for which this conversion is so slow that it may be regarded as substantially non-existent; unfortunately all of these are sufficiently rare and expensive to be unavailable for general waterworks use. Those metals that are normally within the economic reach of the waterworks engineer are all subject to corrosion, and the differences among them are small compared with the differences between them and the so-called noble metals.

The most widely accepted theory of the mechanism of corrosion may be called the electro-chemical theory; this theory is supported by an imposing array of observation and experiment. It represents the corrosion reaction as proceeding in a series of four well-defined steps:

Step I—Anodic Reaction. This is the release of metal ions, each carrying one or more positive charges, to the water, together with the liberation of an appropriate number of electrons, each carrying a single negative charge, to the main mass of the metal. It takes place entirely on the surface of the metal. It is represented below for some of the common metals, the term e signifying an electron:

Iron:	$Fe(metal) \rightarrow Fe^{++} + 2e$	
Zinc:	$Zn \rightarrow Zn^{++} + 2e$	
Lead:	$Pb \rightarrow Pb^{++} + 2e$	
Copper:	$Cu \rightarrow Cu^{++} + 2e$	
Aluminum:	$Al \rightarrow Al^{+++} + 3e$	

Step II—Cathodic Reaction The accumulation of electrons in the metal would soon stop the action by building up a negative charge high enough to prevent the further release of positive ions by sheer electrostatic attraction. However, in the presence of water the surplus electrons can be eliminated by reaction with hydrogen ions from the water. Since the electrons can move freely through the metal, the site of this reaction is not necessarily limited to the same area as that of the anodic reaction and, indeed, often takes place at some distance from it. The reaction is the same for all metals:

$$2H^+ + 2e \rightarrow H_2(gas)$$

When corrosion takes place in a strongly acid solution, the bubbles of hydrogen gas can be seen to form and break away from the surface of the metal. In all other circumstances the hydrogen is removed by another mechanism and may possibly never exist as a gas in the true sense.

Step III—Depolarization. Accumulation of the hydrogen film on the metal again would break the corrosion chain if it were not rapidly eliminated. In the presence of dissolved oxygen this elimination takes place by the reaction of hydrogen and ovygen to form water. The reaction is the same for all metals:

$$2H_2 + O_2 \rightarrow 2H_2O$$

Step IV—Reactions of the Metal Ions. Most of the metal ions released to the water undergo various reactions with ions present in the water. Many of these reactions result in insoluble products that coat the metal and protect it against further corrosion; often the apparent resistance of the metal to corrosion is due to the formation of such coatings. On the other hand, some of these insoluble products crystallize in such a highly previous form that they are of limited value as a protection; iron rust is a good example. The real objective of much of the anti-corrosion treatment of water is to form impervious coatings of one kind or another on the metal by reaction with the substances introduced into the water. A few of the possible reactions of the various metals in natural or treated waters are given here:

Iron: $2Fe^{++} + \frac{1}{2}O_2 + 4OH^- \rightarrow 2H_2O + Fe_2O_3$ (rust)
or $2Fe^{++} + \frac{1}{2}O_2 + 4HCO_3^- \rightarrow 2H_2O + 4CO_2 + Fe_2O_3$
Zinc: $5Zn^{++} + 6OH^- + 2CO_3^= \rightarrow 2ZnCO_3 \cdot 3Zn(OH)_2$ (basic zinc carbonate)

Lead: $Pb^{++} + CO_3^{=} \rightarrow PbCO_3$ (lead carbonate) or $3Pb^{++} + 2CO_3^{=} + 2OH^{-} \rightarrow 2PbCO_3 \cdot Pb(OH)_2$ (basic lead carbonate)
Copper: $2Cu^{++} + CO_3^{=} + 2OH^{-} \rightarrow CuCO_3 \cdot Cu(OH)_2$ (basic copper carbonate)
Aluminum: $2Al^{+++} + 6OH^{-} \rightarrow 3H_2O + Al_2O_3$ (aluminum oxide)

In the presence of other appropriate ions in the water, such as phasphate or silicate ions, insoluble compounds of the metals with these ions will be formed. None of these reactions will occur unless the necessary ions are present in the water in sufficient quantities.

Corrosion is thus seen to be a complex reaction composed of several steps. Interference with any part of the sequence will alter the course or rate of the entire reaction. This explains why corrosion is affected by a large number of factors, and why statements regarding it are so frequently conflicting or confusing. The conflicts come from disregarding factors which are not obvious but which affect materially some part of the sequence of reactions.

Factors That Influence the Steps in the Corrosion Sequence

Step I—Anodic Reaction. The tendency for a metal to release ions to water is a fundamental property of the metal itself. This tendency can be measured; it is called the oxidation potential of the metal. The noble metals are characterized by low values of the potential, the easily corroded metals by high values. Arranging some of the more common metals in order of decreasing tendency to release ions produces the following results:

Aluminum	Tin
Zinc	Lead
Chromium	Copper
Iron	Silver
Nickel	Gold

If no steps other than the release of ions were involved in corrosion, this series would represent the comparative susceptibility of these metals to corrosion. However, other factors complicate the picture. Aluminum, zinc, and chromium all appear ahead of iron in this series and on this basis alone would be expected to be more susceptible to corrosion than iron, but all three of these metals are much more corrosion-resistant than indicated by their position, because in step IV of the sequence they form impermeable films of oxide or other compounds, whereas iron does not. Under circumstances which prevent the formation of these films, the three metals take their proper place in the series. Such conditions are, however, not likely to occur in practice; hence these metals enjoy a high reputation for resistance to corrosion. Alloying of a metal with another will also alter its relative position in the series.

Step II—Cathodic Reaction. The ease with which hydrogen can be deposited on various metal and other surfaces is subject to considerable variation. It is, for example, more difficult to deposit hydrogen on zinc or tin than on iron, and easier to deposit it on certain oxides of iron than on the metal itself. This accounts in part for the protective action exercised by galvanizing or tinning, and for the localized corrosion or pitting produced by a piece of mill scale on an iron surface. In the latter case the mill scale becomes a cathodic area at which hydrogen is discharged, and the anodic reaction is concentrated in areas near the piece of scale, resulting in a strongly localized attack. Similarly, if two different metals are placed in contact with each other, the one lower in the series shown previously will become the cathodic area and the attack will be concentrated on the one higher in the series.

The rate of discharge of hydrogen is also influenced by the hydrogen-ion concentration (or the pH value) of the water in contact with the metal. Three ranges of hydrogen-ion concentration can be distinguished:

1. The acid range, corresponding to pH values of about 4.5 or lower. In this range the rate of corrosion is directly related to the hydrogen-ion concentration and the hydrogen is evolved directly as gas.

2. The intermediate range, from a pH value of about 4.5 to one of about 10.0. In this range the importance of the hydrogen-ion concentration is small compared to that of other factors, and the corrosion rate varies little, if at all, with pH value. Sometimes this fact is obscured by the influence of the pH value on the formation of protective films of certain types, notably carbonate and silicate films.

3. The alkaline range, corresponding to pH values of 10.0 or greater. In this zone the formation of hydroxide, carbonate, or other films is a direct function of the pH value, and corrosion accordingly again depends greatly on the pH value.

Step III—Depolarization. In waters possessing pH values between 4.5 and 10.0 the depolarization of hydrogen by dissolved oxygen is of great importance to the corrosion sequence. The oxygen concentration and the velocity of flow, which determines how fast fresh oxygen is brought to the metal, both exert a great influence on the rate of corrosion. Complete removal of dissolved oxygen from water will substantially eliminate its power to attack metals in this zone of pH values. Unfortunately, complete removal of dissolved oxygen is seldom feasible in waterworks practice.

If the concentration of oxygen varies at points along the surface of the metal, the areas where the concentration is high become cathodic areas and those where it is low, anodic areas. The attack is concentrated at the anodic areas, and pitting is produced.

Step IV—Reactions of the Metal Ions. Corrosion can be stopped very effectively if a layer of impervious non-metallic material is interposed between the metal surface and the water. Obviously such a material—for example, asphalt or cement—may be deliberately applied to the metal; the effectiveness of such a coating will depend on the imperviousness of the material and the care with which it is applied.

Many of the metals, under suitable conditions, will react with components present in the water to form impervious films that protect the metal from further attack. A complete catalogue of such films would be a major undertaking, but a few of the more common ones may be mentioned here. Films made up of oxides or hydroxides of the metal are numerous; aluminum, chromium, zinc, and iron are familiar examples. Carbonates or basic carbonates of the metal are also common, such as, for example, those formed by zinc and copper. Under special conditions, films of metal silicates and phosphates or of metals combined with organic radicals may be encountered.

In other cases the protecting film may be formed entirely from substances present in the water, without much involvement of the metal ions; examples are the films of calcium carbonate or silicate produced by certain types of anti-corrosion treatment of the water and the protection afforded by some types of organic compounds.

These protecting films vary tremendously in thickness; furthermore, some are effective barriers against corrosion when only one molecule thick, whereas others are relatively ineffective even when present as a heavy deposit. The composition of the water and numerous other factors affect the stability, composition, and physical structure of the films. In short, it is this latter step in the corrosion process that exhibits the greatest complexity and accounts for most of the observed variability in the total rate of attack on metals.

III. Methods of Mitigation of Corrosion

A. Self-Corrosion

Self-corrosion is that resulting from the inherent tendency of all metals to dissolve in water, aqueous solutions of water-soluble materials, or mixtures of water with some other substance which is neither soluble in nor a solvent for water. It is known as electro-chemical corrosion and is the type of corrosion commonly found in piping systems. This discussion applies primarily to water systems. Self-corrosion may be mitigated by

(1) Selection of materials
(2) The use of protective coatings
(3) Treatment of the water

These topics are treated below.

1. **Selection of Materials.** Pipe may be non-metallic and there are many varieties of such pipe available. For the waterworks industry, however, only asbestos-cement pipe, concrete pipe (and masonry conduits) and wooden pipes are at present suitable and practicable. Of these, wooden pipe is now used only as wood stave pipe and its use in the eastern section of the country is practically non-existent except in some waterpower developments.

Asbestos-cement pipe withstands salt water and soft and corrosive waters, but not acids. It is available for mains only and for such use is an important competitor of metallic pipe. It has been found to increase the alkalinity and hardness of water when first installed, an effect which gradually diminishes but may persist for six months or more. Recent methods of manufacture have greatly reduced this leaching characteristic. The *N.E.W.W.A. Journal*, Vol. 51, No. 3 (September 1937), contains a series of papers on the manufacture, laying, and use of asbestos-cement pipe.

Concrete pipe is increasingly used for large mains. The present outstanding example of the use of pipe of this type is the Hultman Aqueduct of the Boston Metropolitan Supply, described in detail in the *N.E.W.W.A. Journal* for September 1941, page 315.

For service connections and interior and other small piping, there are available pipes of various corrosion-resistant metals such as copper, brass, lead, tin, monel, stainless steel, silicon, bronze, nickel-molybdenum-chromium-iron alloys, and others.

Copper is highly resistant to corrosion, but for very soft waters containing large amounts of carbon dioxide, tin-lined copper is to be preferred.

Brass pipe containing 85 per cent or more of copper (red brass) is highly resistant to corrosion. Brass pipe containing 60 per cent or less of copper will dezincify in soft waters; 67 per cent copper (alpha) brass is fairly resistant. Green stains and precipitates may appear when copper or brass pipe is used with very soft waters containing large amounts of carbon dioxide.

Lead pipe should never be used with soft waters because of the toxicity of lead salts. It is suitable for hard waters.

The other corrosion-resistant materials noted above are in general too expensive for use as water pipes and are used mostly in special work, though silicon bronze is used extensively in sewage plants, especially for valves, sluice gates, and stop shutters.

2. **Protective Coatings.** "When pipe material is subjected to corrosive conditions to which it is susceptible, some form of protective coating may be more economical than resorting to a more resistant but more expensive material. Since corrosion may arise from the fluid conveyed by the pipe, from the atmosphere, or from the soil environment in the case of a buried pipe, protection may be needed either internally or externally, or both, depending on circumstances. In the case of internal attack, it may be possible to reduce the corrosive nature of the fluid conveyed."*

Protective coatings and linings for ferrous pipes, valves, and fittings may be (a) non-metallic or (b) metallic.

a. The NON-METALLIC COATINGS most commonly used are paints, asphaltic or bituminous materials, and cement. For special purposes, such as the handling of chlorine and chlorine compounds, rubber-lined pipe is also available.

(i) Paints, while effective against atmospheric corrosion, are less so against underwater and underground corrosion. Therefore they are seldom used for underground pipes but rather for ferrous valves and for submerged steel structures where galvanizing is not practicable or the expense of galvanizing is not warranted. Paints commonly used in waterworks equipment, especially that subjected to submergence or damp atmosphere, have asphaltic or bituminous bases often applied over a base coat of red lead.

(ii) Asphaltic or bituminous linings and coatings are made from natural asphalt or coal-tar pitch. They are applied hot by dipping or by spinning. The A.W.W.A. standard specifications for cast-iron water pipe and fittings cover in detail the approved practices of coating cast-iron pipe with hot coal-tar pitch varnish by dipping. In waterworks practice no other coating is normally applied to cast-iron pipes.

Steel pipes with its greater susceptibility to corrosion and its lesser thickness as compared with cast-iron pipe requires, in general, more attention to coating, especially the external coating of submerged or buried pipes. For steel water mains the A.W.W.A. has formulated specifications for coal-tar enamel coatings (AWWA 7A.5 and 7A.6).

The corrosion protection provided under these specifications is as follows:

For the inside of all steel pipe, a coat of coal-tar primer followed by a hot coat of coal-tar enamel applied either by manual or by mechanical means.

For the outside of pipe, 30 inches and over to be placed underground, a coat of coal-tar primer followed by a hot coat of coal-tar enamel and one coat of water-resistant whitewash.

For the outside of steel pipe smaller than 30 inches to be placed unnderground, a coat of coal-tar primer followed by a hot coat of coal-tar enamel into which is bonded an asbestos felt wrapper, with a finish coat of kraft paper or one coat of water-resistant whitewash.

For the outside of all steel pipe to be placed above ground exposed to the weather, two coats of synthetic red lead primer (or one coat of synthetic red lead primer and one coat of synthetic white enamel) and one coat of aluminum paint.

(iii) Cement linings or coatings. Cement-lined ferrous pipe and fittings, both cast-iron and steel, are used extensively in New England. The A.W.W.A. has prepared specifications (AWWA 7A.7) for "Cement-mortar Protective Coating for Steel Water Pipe 30 inches and over" and a similar specification for cast-iron pipe. Cement-lined pipe, both steel and cast-iron, conforming thereto are commercially available. Mains may also be lined in place by patented processes. Cement linings have the same temporary effect on quality of water when first installed as has asbestos-cement pipe. A cement lining is not wholly impervious to water, but water that penetrates forms an alkaline solution in contact with the iron and tends to inhibit corrosion. Water of low pH value, however, continually reacts with the coating so that cement-lined pipe is not suitable for highly acid waters.

b. *Metal coatings of ferrous pipe.* Of the various metallic coatings and linings available, the most commonly used in waterworks are zinc and lead.

Hot-dip galvanizing is the simplest and commonest method of applying zinc to steel pipe, and the use of pipe galvanized by this method is widespread in interior piping, service connections, and to a limited extent in small mains. Galvanizing provides reasonably good protection against atmospheric corrosion, but it is a poor type of protection with some waters. Zinc is protective because it is anodic with respect to iron and it is intended to be consumed by corrosion. Too long life should not be expected of it. ASTM specification A 120-44 covers hot-dipped zinc-coated steel pipe.

Lead-lined pipe and fittings are suitable for sea water and weak acids but should never be used with soft domestic waters because of toxicity. Since lead is cathodic with respect to iron, a lead lining must be continuous, eliminating any access of the liquid to the iron. This necessitates the use of flanged joints with the lead lining turned back over the face of the flange.

Other metallic linings and coatings are available, but in general they are used mainly for protection against atmospheric corrosion and their value for water pipe and fittings is doubtful. They may be listed briefly here. *Aluminum* may be applied by "calorizing," a process similar to Sherardizing. *Copper, nickel, chromium,* and *cadmium* may be applied by electroplating. There are also processes or treatments which alter the surface of the iron (such as Parkerizing, Bonderizing, anodizing, etc.) and produce moderately corrosion-resistant films of iron oxides or phosphates on the surface.

c. *Natural protective coatings.* Under certain conditions mineral coatings, coatings formed by corrosion products, and by those formed by organic slime, appear to act as corrosion inhibitors. Deposits of mineral coatings of calcium carbonate or of silicates, due to the presence of those substances in the water, may occur to retard corrosion, and this phenomenon explains the lower corrosiveness of hard waters. Oxides, hydroxides, carbonates, basic carbonates, silicates, etc., of the metals, formed by reaction of dissolved metals with substances in the water may form coatings which cause a decrease in the rate of corrosion and may ultimately stop it almost completely. Organic slimes also retard corrosion, a fact accounting partly for the observation that filtered waters are often more corrosive than unfiltered.

3. **Mitigation of Corrosion by Treatment of Water.** There are a number of methods of altering the composition of water so that its corrosive attack on metals is diminished; on analysis, most of these can be classified under one or more of the following groups:

a. *Treatments that reduce the hydrogen-ion concentration of the water.* This covers the use of the ordinary alkaline agents such as soda ash and caustic soda.

b. *Treatments that induce deposition of mineral films on the metal.* This includes treatments to produce calcium carbonate saturation, treatments with silicates, and probably also the treatments with complex phosphates.

c. *Treatments with organic corrosion inhibitors.* These substances deposit organic protective films on the metal; they include an enormous range of compounds, from glue to complex amines.

d. *Treatment with passivating agents.* These are strong oxidizing agents that convert the metal surface to an impervious oxide film.

e. *Treatments to remove dissolved gases, principally dissolved oxygen, secondarily carbon dioxide.*

Items c and d are not applicable as yet to the treatment of drinking water, since the substances used are toxic or otherwise objectionable and yet must be used in moderately large quantity to be effective. Item e is rarely employed in waterworks practice because of technical difficulties, although removal of carbon dioxide by aeration is sometimes practiced as an anti-corrosion measure. In this case its value is dubious, since the oxygen added may be much worse than the carbon dioxide removed. Carbon dioxide is also destroyed in process a. This leaves us with items a and b as our main reliances in corrective treatment of water.

4. **Applications of Methods.** In practice it is often difficult to separate and evaluate methods a and b, since in many waters treatment with alkaline reagents of any sort will produce supersaturation of the water with calcium carbonate, calcium silicate, or a number of other similar compounds capable of acting as protective films. However, in many of the soft waters of New England the separation is very well defined, since the content of calcium is such that no reasonable amount of treatment with the sodium alkalies will produce supersaturation with calcium salts. In this case the two types of treatment can be discussed separately.

a. *Treatment to reduce the hydrogen-ion concentration or to raise the pH value.* This type of treatment has as its objective the slowing of *Step II* in the corrosion chain by making hydrogen ions less available. As previously noted in the theoretical discussion, this procedure is relatively ineffective in the pH zone from 4.5 to 10.0, which covers most natural and treated waters.

The chemicals used in practice are principally soda ash and caustic soda, which are added in amounts sufficient to produce a desired pH value. The statement above regarding the pH zones in which such treatment is effective has been confirmed by the experience of many New England waterworks operators, who have had little success with this type of treatment. It is much more successful in harder waters, but here it succeeds through the combination of the alkaline agents with the calcium of the water to produce protective films.

b. *Treatment to produce deposition of mineral films.*

(i) *Calcium carbonate films.* Water treated so as to produce a condition of saturation or near-saturation with calcium carbonate shows a great decrease in its ability to attack metals, although the attack is not entirely eliminated. The reduction is due to the tendency of the water to deposit, on the metal, films composed in part of calcium carbonate, and in part of carbonates of the metal itself. The type of treatment required to produce a condition of saturation varies with the composition of the water. Hard waters may require only the addition

*"Piping Handbook" by Sabin Crocker.

of soda ash; soft waters with moderate amounts of alkalinity will require only lime, but soft waters of very low alkalinity may need both.

The quantitative relationships involved in such treatments were developed originally by Langelier (*Jour. Amer. Water Works Assn. 25*, 1500, 1936) and extended by him and others (Moore, *Jour. New England Water Works Assn. 52*, 311, 1938; Hoover, *Jour. Amer. Water Works Assn. 30*, 1802, 1938; Langlier, ibid. 38, 169, 1946) to allow calculation, from the analysis of the water, of the chemicals needed for treatment. Previous to Langlier's work, Baylis had shown how the treatment required could be determined by testing treated samples against calcium carbonates; this is the so-called "marble test," adapted by Enslow for continuous operation with his stability indicator.

While the protection against corrosion afforded by treatment of water to calcium carbonate saturation is not absolute, it is still the most widely used method of controlling corrosion by water treatment. The chemicals used are relatively inexpensive and are already familiar to the waterworks operator through their other applications in waterworks practice. There are few problems involved in dosing, and under-or overdosing for short periods has little noticeable effect.

(ii) *Silicate films.* The addition of soluble silicates (principally sodium silicate) to water in sufficient quantities will produce incipient precipitation of calcium silicate or of silicates of the metals in contact with the water. The metals will tend to become coated wth silicate films, which appear to provide good protection. Not so much is known of the quantitative relationships involved in silicate film formation as in the formation of carbonate films. However, there are numerous instances of successful treatment with silicates in which dosage has been determined by experience. Dosing involves no great problems; the silicates are physiologically harmless and the quantities required are small.

(iii) *Polyphosphate films.* The complex glass-like sodium phospates so-called meta- and pyro-phosphates—are a comparatively new discovery in anti-corrosion treatment. When added to water in relatively small quantities, under proper conditions, there is no doubt that they will materially reduce the rate of attack on ferrous metals. The presence on the metal of a film, only a few molecules thick, of phosphate-containing material, is demonstrated by the appearance of "interference colors." At present this film is believed to consist of compounds of the polyphosphates with the metal or with calcium from the water. The polyphosphates are relatively expensive per pound, but the smallness of the dose required allows them to compete favorably with the anti-corrosion treatments mentioned previously. The treatment is simple in application, involves less increase in the mineral solids of the water than other methods, and has as a consequence been widely adopted during the past few years. In beginning polyphosphate treatment on old, heavily incrusted piping systems, difficulty has occasionally been experienced through the tendency of the polyphosphates to strip off the old deposits and disperse them in the water. Some care is required in the initial application to avoid complaints of turbid or red water.

B. Galvanic Action

As stated in Section II of this report, there is a tendency for each metal to release ions to the water in which it is immersed, and this tendency is different for the different metals. This solution pressure may be expressed in terms of electrical voltage. As already noted, the metals may be arranged in a table in order of decreasing solution pressure. Such a table is referred to as the "electrochemical" or "electromotive" series of the elements. The following series includes the metals commonly encountered in the waterworks field.

Electrochemical Series of the Elements

Aluminum
Chromium
Zinc
Iron
Nickel
Tin
Lead
Hydrogen
Copper
Silver

When two dissimilar metals in contact with each other are immersed in water, the metal that stands higher in the series will tend to release metal ions to the solution, while hydrogen will be formed on the one lower in the series. With reference to the nomenclature used in Section II, the anodic reaction occurs on the metal higher in the series, and the cathodic reaction on the one lower in the series. This results in a flow of current through the solution from the point where the metal is going into solution to the point where hydrogen is being plated out and a similar flow of current in the opposite direction across the junction of the two metals. The metal higher in the series undergoes rapid corrosion, while the corrosion rate of the metal lower in the series is negligible. The entire process is spoken of as "galvanic action." The steps in the process are influenced by the same factors that were described in Section II-A for ordinary corrosion. The extent of galvanic action is also influenced by the difference in potential between the two metals undergoing corrosion and by the relative area of the two metals. If the area of the metal lower in the series (the cathodic area) is large compared with the anodic area, corrosion will be more extensive because there is a large area available for the discharge of the hydrogen that is formed. The extent of galvanic action is also influenced by the conductivity of the solution. In the case of soft waters of very low mneral content and therefore low conductivity, galvanic action will occur only over an area of an inch or so on either side of the junction of the dissimilar metals. With waters of high mineral content, the area of activity may extent somewhat farther.

The solution potential of alloys differs from that of pure metals, and even the processing of a metal will change the electrochemical potential of the section of metal processed. The oxides of a metal likewise have a different solution potential from the original metal. Thus mill scale has a different potential from the iron of the pipe. For these reasons, and because the use of dissimilar metals is quite common in piping systems, galvanic corrosion is quite common. However, as previously stated, the effects of galvanic action are usually limited to a small area in the vicinity of the junction of the dissimilar metals and the extent of galvanic action is minimized by all of the various factors that were pointed out under the discussion of corrosion.

Galvanic action can be kept at a minimum by using the same metal as far as possible throughout the piping system. For example, the use of brass faucets, bronze valve bodies, and brass or bronze fittings with iron piping should be avoided. Where dissimilar metals are absolutely necessary, the choice should be metals as near together in the electromotive series as possible. There have been attempts to reduce the effects of galvanic action by the insertion of a short section of non-conducting piping, such as plastic or hard-rubber piping, between sections of dissimilar metal piping. This procedure will eliminate galvanic action, but it adds materially to the cost and complexity of installation.

C. Stray Current Electrolysis

Stray electric currents may produce corrosion in underground pipes. Under normal conditions only direct currents will produce such corrosion. In a direct-current railway system and in the distribution of direct-current electricity, one side of the system is grounded. If there are defective grounds or defective bonding of the rails of streetcar lines, some current will find its way back to the substation or power station through the earth, and in seeking the path of least resistance current may enter an underground pipe at one point and leave it again at another. Since the pipe at the points or areas where such stray currents leave the pipe is anodic to the earth, corrosion will occur at those points. It may be severe. The remedies consist of providing more direct paths—paths of lower resistance—back to the station. Among these remedies the following may be noted: (a) for streetcar systems: the use of a two-trolley system, thorough bonding of the rails, the use of heavy pipe covering to serve as an insulator in the vicinity of the substation or power plant, insulation of the pipe joints, and the use of drain cables to take the current off the pipe; (b) for ground connections to water pipes: careful checking of all grounds of electric, telephone, and radio systems to see that they have no potential and therefore carry no current.

ALKALINITY EQUIVALENTS

AMONG the mineral compounds present in natural waters, Calcium Carbonate is the most ubiquitous. Partly for this reason and partly because its molecular weight at the time, was thought to be exactly 100, this compound was chosen as the standard to be employed in the measurement of alkalinity and hardness.

With more accurate determination of atomic weights, the molecular weight of Calcium Carbonate is now assumed to be 100.08. Very obviously, tables earlier prepared under the assumption that the molecular weight was 100 will have a small and not entirely negligible error if the true weight be 100.08. The accompanying table, based upon the newer molecular weight of 100.08 for Calcium Carbonate, are arranged in such manner as to facilitate comparisons against other substances having different values of alkalinity. These values are presented as being more accurate than those appearing in earlier tables computed on the old 100 molecular weight value assumed for Calcium Carbonate.

A brief explanation of how the tables may be used follows.

In the sixth column, sixth line, the unity of Calcium Carbonate may be compared directly against every other factor in the column. For instance, one part of alkalinity, due to Calcium Carbonate, is the exact equivalent, in alkalinity value, to that which would be imparted by 1.6196 of Calcium Bicarbonate; 0.7403 of Calcium Hydroxide; 0.8424 of Magnesium Carbonate; 1.0590 of Sodium Carbonate (dehydrated), etc.

Along the line, right or left, a different comparison may be made. The molecular weight, for instance, of Calcium Bicarbonate, is in excess of that of Calcium Carbonate. Therefore, it takes more Calcium Bicarbonate to produce a given alkalinity than it does of Calcium Carbonate, and it is found that for an equal weight of Calcium Bicarbonate the alkalinity value as compared against Calcium Carbonate is only 0.6174 parts. On the other side an equal weight of Calcium Hydrate will have an alkalinity value of 1.3506 parts; Sodium Hydroxide 1.2508—and so on.

From the foregoing it is seen that the compounds in these tables may be compared in two different ways against the Calcium Carbonate Standard for alkalinity, or against any other compound in the table. For instance, under the heading Sodium Hydroxide (NaOH) it is noted that one part is equal in alkalinity value to 1.3247 parts of Sodium Carbonate (Soda Ash); and, further, that one part of Sodium Carbonate is only equal to 0.9442 parts of Calcium Carbonate in raising alkalinity values.

ALKALINITY EQUIVALENTS*

Compound	Formula	$Al_2(OH)_6$	BaO	$Ba(OH)_2$	CaO	$Ca(OH)_2$	$CaCO_3$	$CaH_2(CO_3)_2$	MgO	$Mg(OH)_2$
Aluminum Hydrate	$Al_2(OH)_6$	*1.0000*	0.3390	0.3034	0.9271	0.7017	0.5195	0.3207	1.2895	0.8913
Barium Oxide	BaO	2.9494	*1.0000*	0.8948	2.7734	2.0697	1.5323	0.9461	3.8035	2.6289
Barium Hydrate	$Ba(OH)_2$	3.2959	1.1174	*1.0000*	3.0559	2.3128	1.7123	1.0572	4.2503	2.9377
Calcium Oxide	CaO	1.0785	0.3656	0.3272	*1.0000*	0.7568	0.5603	0.3459	1.3908	0.9613
Calcium Hydrate	$Ca(OH)_2$	1.4250	0.4831	0.4323	1.3212	*1.0000*	0.7403	0.4571	1.8376	1.2701
Calcium Carbonate	$CaCO_3$	1.9247	0.6525	0.5839	1.7845	1.3506	*1.0000*	0.6174	2.4821	1.7155
Calcium BiCarbonate	$CaH_2(CO_3)_2$	3.1174	1.0569	0.9458	2.8904	2.1876	1.6196	*1.0000*	4.0202	2.7786
Magnesium Oxide	MgO	0.7754	0.2629	0.2352	0.7189	0.5441	0.4028	0.2487	*1.0000*	0.6911
Magnesium Hydrate	$Mg(OH)_2$	1.1219	0.3803	0.3403	1.0402	0.7873	0.5828	0.3598	1.4468	*1.0000*
Magnesium Carbonate	$MgCO_3$	1.6216	0.5498	0.4920	1.5035	1.1379	0.8425	0.5201	2.0912	1.4454
Magnesium BiCarbonate	$MgH_2(CO_3)_2$	2.8143	0.9541	0.8538	2.6094	1.9749	1.4621	0.9027	3.6293	2.5085
Sodium Oxide	Na_2O	1.1922	0.4042	0.3617	1.1054	0.8366	0.6194	0.3824	1.5375	1.0627
Sodium Hydrate	NaOH	1.5387	0.5217	0.4668	1.4267	1.0798	0.7994	0.4935	1.9843	1.3715
Sodium Carbonate	Na_2CO_3	2.0385	0.6911	0.6184	1.8900	1.4305	1.0590	0.6538	2.6288	1.8169
Sodium Carbonate, Hydrated	$NaCO_3.10H_2O$	5.5033	1.8658	1.6697	5.1025	3.8619	2.8592	1.7653	7.0969	4.9052
Sodium BiCarbonate	$NaHCO_3$	3.2312	1.0955	0.9803	2.9958	2.2674	1.6787	1.0364	4.1669	2.8800
*Tri-Sodium Phosphate	Na_3PO_4	2.1028	0.7129	0.6380	1.9497	1.4756	1.0925	0.6745	2.7118	1.8743
Tri-Sodium Phosphate, Hydrated	$Na_3PO_4.12H_2O$	4.8747	1.6527	1.4790	4.5197	3.4207	2.5326	1.5636	6.2863	4.3449

Compound	Formula	$MgCO_3$	$(CO_3)_2$	Na_2O	NaOH	Na_2CO_3	Na_2CO_3 $10H_2O$	$NaHCO_3$	Na_3PO_4	Na_3PO_4 $12H_2O$
Aluminum Hydrate	$Al_2(OH)_6$	0.6166	0.3553	0.8387	0.6498	0.4905	0.1817	0.3094	0.4755	0.2151
Barium Oxide	BaO	1.8187	1.0480	2.4737	1.9167	1.4468	0.5359	0.9128	1.4025	0.6050
Barium Hydrate	$Ba(OH)_2$	2.0324	1.1711	2.7643	2.1419	1.6168	0.5989	1.0200	1.5672	0.6761
Calcium Oxide	CaO	0.6650	0.3832	0.9046	0.7009	0.5290	0.1959	0.3337	0.5128	0.2212
Calcium Hydrate	$Ca(OH)_2$	0.8787	0.5063	1.1952	0.9260	0.6990	0.2589	0.4410	0.6776	0.2923
Calcium Carbonate	$CaCO_3$	1.1869	0.6839	1.6143	1.2508	0.9442	0.3497	0.5956	0.9152	0.3948
Calcium BiCarbonate	$CaH_2(CO_3)_2$	1.9223	1.1076	2.6146	2.0259	1.5292	0.5664	0.9647	1.4824	0.6395
Magnesium Oxide	MgO	0.4781	0.2755	0.6503	0.5039	0.3803	0.1409	0.2399	0.3687	0.1590
Magnesium Hydrate	$Mg(OH)_2$	0.6918	0.3986	0.9409	0.7291	0.5503	0.2038	0.3472	0.5334	0.2301
Magnesium Carbonate	$MgCO_3$	*1.0000*	0.5762	1.3601	1.0538	0.7955	0.2946	0.5018	0.7711	0.3326
Magnesium BiCarbonate	$MgH_2(CO_3)_2$	1.7354	*1.0000*	2.3604	1.8289	1.3806	0.5113	0.8709	1.3382	0.5773
Sodium Oxide	Na_2O	0.7352	0.4236	*1.0000*	0.7748	0.5848	0.2166	0.3689	0.5669	0.2445
Sodium Hydrate	NaOH	0.9488	0.5467	1.2906	*1.0000*	0.7548	0.2796	0.4762	0.7317	0.3156
Sodium Carbonate	Na_2CO_3	1.2570	0.7243	1.7097	1.3247	*1.0000*	0.3704	0.6308	0.9693	0.4181
Sodium Carbonate, Hydrated	$NaCO_3.10H_2O$	3.3936	1.9554	4.6157	3.5764	2.6996	*1.0000*	1.7031	2.6169	1.1289
Sodium BiCarbonate	$NaHCO_3$	1.9925	1.1481	2.7100	2.0998	1.3850	0.5871	*1.0000*	1.5364	0.6628
Tri-Sodium Phosphate	Na_3PO_4	1.2967	0.7471	1.7637	1.3665	1.0315	0.3821	0.6504	*1.0000*	0.4313
Tri-Sodium Phosphate, Hydrated	$Na_3PO_4.12H_2O$	3.0059	1.7320	4.0885	3.1679	2.3913	0.8857	1.5078	2.3181	*1.0000*

* Prepared by the late C. Arthur Brown, of Lorain, Ohio.

CORROSION CONTROL BY THRESHOLD TREATMENT*

JOHN H. WHITE†
Chemical Engineer, Boston, Mass.

APPROXIMATELY ten years ago the use of Calgon for corrosion control was introduced to the American public. The small amount of inhibiter required met the fancy of the water works men, and the use of Calgon for corrosion control has had quite general acceptance.

What Is Calgon?

Calgon is a glassy phosphate made of good grade raw materials and is also referred to as metaphosphate or sodium hexametaphosphate. The raw materials, usually phosphoric acid and soda ash, are fused at high temperatures and then quickly cooled to normal temperature. To obtain a product which is highly soluble and of the desired property, both temperature ranges must be closely controlled.

There is quite a difference between the true chemical and the physical reactions of Calgon, which at first may seem to be inconsistent. A strong solution of Calgon is corrosive to most metals, and it can even be considered a solvent. This is particularly true of iron and steel, and when the solution tank shows slight corrosion we are asked how this can happen when such a small concentration is being used to protect the system. However, the dilute solution loses this chemical solvency which will be gone into later in more detail and assumes surface active properties which result in the laying down of the protective film. It is these physical or surface active properties of Calgon in which we are primarily interested as water works men.

Calgon is being used to prevent the laying down of calcium scale in hard water districts, but in New England where waters are relatively soft, little use of this property is anticipated.

Another use is for iron control in well water supplies containing ferrous iron which later precipitates on standing or in the presence of air. A number of systems in New England are using Calgon for this purpose and are obtaining clear, colorless water.

Corrosion Control

The main use, however, will be in corrosion control. Here we are using a principle almost as old as the use of metallic pipe itself. Most corrosion control depends upon the formation of a protective scale or film or of making a protective coating such as the metallic oxide more stable or adherent. These steps require the altering of the composition of the water itself, and particularly in the case of the protective scale close chemical control is required to prevent too rapid a build-up in the first part of the system and yet get some protection at the end.

From a practical standpoint such control becomes impossible and a compromise is necessary. Such a compromise is one which does not give the desired protection but which likewise does not result in plugging up the system too rapidly. Some protective coatings can be applied mechanically with the systems out of service or before the pipe is installed, and as these coatings are uniform in thickness and usually impervious to the water, protection is achieved for the life of the lining.

With Calgon a protective film is formed in the pipe. This film is one or two molecules thick and never grows any thicker. Therefore, it forms uniformly throughout the system and being impermeable gives very good protection not only in the main but in the consumers' piping as well. The control is quite simple and in most cases once the feed is established an occasional check of the residual Calgon at the ends of the system is satisfactory. The small quantity of Calgon required does not alter the taste, odor, color, hardness, or pH value of the water. Likewise the cost over a long period of time seems comparable to the cost of coating mechanically installed in a system.

Factors Involved

One factor involved in applying Calgon to a distribution system is the flow or rate at which the Calgon is supplied to the metal surfaces. The lower the flow through a given distribution system, the higher the Calgon concentration should be to insure maintenance of the protective film. This is a very definite relationship and it has been shown that if ten pounds of Calgon per day will protect a system at a certain flow the same quantity of chemical will protect the system should the flow increase fifty per cent. On the other hand if the original flow should be decreased fifty per cent, it is quite likely that ten pounds of chemical will be required per day, all other factors remaining the same.

A second factor, that of surface of the system, fits right in with the flow factor, as, of course, the Calgon requirements would be based on a ratio between the flow and the surface involved. The surface of the system, however, would include not only the metal but the presence of rust and other suspended or dispersible solids that are present in the system. With rust and tuberculation in a system a higher feed of Calgon would be required at the beginning, and perhaps flushing should be employed during the starting up period to remove such of this material as is dispersed by the chemical.

A third factor involved in corrosion control is the presence of various salts in the water. From a practical standpoint this factor is taken care of quite satisfactorily, but by understanding the principle involved a better understanding of the formation of the protective film will be obtained. This protective film, which is depended upon for corrosion control, will not be formed in a distilled water system. However, upon the addition of calcium salt to the distilled water the protective film will form and can be maintained. Other salts such as those of iron react similarly. As calcium salts are present in natural waters this factor does not have to be considered unless excessively high feeds are contemplated, inasmuch as sufficient of these salts will be present to satisfy the requirement. It is only necessary to have the calcium content of the water one-quarter that of the Calgon concentration to obtain a good protective film formation. Thus with a normal feed of 2 ppm. of Calgon, the calcium (as Ca) content of the water would have to be at least 0.5 ppm. However, to feed 200 ppm. of Calgon for rapid film formation, the calcium content should be 50 ppm. This would have some value in protecting small systems where little circulation is experienced, or as will be described later for preforming the film when batch type corrosion experiments are to be made.

Calgon controls corrosion throughout the pH range normally encountered in water. Excellent corrosion control can be obtained and pH values as low as 5.0. A reduction in the amount of corrosion encountered can be obtained at pH values below this, but the efficiency seems to decrease. At pH values under 7 the corrosion that does take place is general in nature and will be neither noticeable nor troublesome. At pH values much above 8.0 any corrosion may leave an adherent deposit and is likely to be more localized in nature. Less corrosion will be encountered, however, with Calgon than under similar conditions in the absence of Calgon.

To Prevent Iron Precipitation

The use of Calgon for prevention of iron precipitation in well waters is probably the most spectacular use as far as the consumer is concerned. There are a number of well water supplies which contain small amounts of iron which can make the water look bad. It would be uneconomical, however, to construct an iron removal plant considering the quantity of water distributed from such wells As a usual thing, the iron present in these well waters is in the ferrous state which precipitates on standing as hydrous ferric oxide. The same is also true where manganese is present.

Unlike corrosion control where the chemical did not have to be proportioned to the flow or the constituents of the water, in controlling iron and manganese there is a definite relationship between the amount of these salts and the Calgon required. For some industrial waters equal parts of Calgon to the total iron and manganese content will prevent precipitation and allow some color to develop. For domestic water, however, Calgon concentration of at least twice the iron and manganese concentration is advisable and four times the concentration is quite desirable when a minimum of color is desired in the hot water system. Water treated with four parts of Calgon for every part of iron and manganese can be used for normal household purposes without showing the presence of iron.

Likewise various persons have reported an improvement in the taste, although the absence of color may influence them greatly in this observation. There is no limit except economy to the amount of iron which can be kept in solution by Calgon. Numerous industrial installations are using Calgon to hold up 4 to 5 ppm. of iron, and there are quite a number of domestic water supplies where the iron content of 0.5 to 1 ppm. is maintained in solution.

In using Calgon for the prevention of iron and manganese precipation it is only necessary to use the proper quantity and to feed it to the system before air or chlorine is introduced. This usually means feeding the chemical to the suction side of the well pump if it is possible to do so. If wide variation in the flow is encountered

*A paper presented before the New England Water Works Assn. and here published by permission.
†Associated with Ralph L. Williams, Agt. for Calgon, Inc., 49 Federal St., Boston, Mass.

the Calgon should be fed to take care of the maximum flow or else a proportioning system used.

To Test Effectiveness

It is possible to take two test tubes containing a water in question, drop a nail in each of them and a little Calgon in one, shake them up, let them stand over night, and observe the difference in the morning as a means of determining Calgon effectiveness. The best way to test the Calgon and sometimes the cheapest way is to add the proper amount to the system for a period long enough to obtain acceptable analytical results. By following the iron or dissolved oxygen content of the water at various ends of the system and comparing these results with the analyses of the water as it enters the system gives an excellent indication of how corrosion is being controlled. For larger systems where this would not be feasible a small quantity of the water can be treated and observations made either by using weighed sections of tubing or by measuring the iron or oxygen content before and after passing through this pilot plant type setup.

Inasmuch as flow is an important factor, an adequate amount of water should be used, and an attempt should be made to simulate the flow in the distribution system. A test like this carried out over an extended period of time will clearly indicate whether or not Calgon will give the desired results.

Batch Tests

Where batch type tests are desired it should be assumed that the test is to determine whether or not the protective film can be laid down on the type of metal under consideration. Such tests are usually for a relatively short period by their very nature. We suggest, therefore, the preformation of the protective film on the test specimens by agitating them in a solution containing several hundred ppm. of Calgon in about one liter of solution. In this case the calcium content of the solution should be at least one-quarter of the Calgon content. Either air or mechanical agitation may be employed.

The length of time required to obtain this film in equilibrium is not very great and approximately one hour should be sufficient immersion time. Thereafter the natural water should be used and any loss in weight of the specimen or any pickup of iron or other metallic salts by the water should be noted. The volume of water used for this test should be at least 20 l. and the Calgon concentration should be at least 5 ppm. Mechanical agitation should be employed although equally satisfactory results have been obtained using air for agitation; but the bubbling of air through the water will, of course, tend to change its properties.

If 5 ppm. or even 10 ppm. gives the desired result this does not mean that the concentration will have to be that high to achieve protection of the system. The Calgon feed should be such as to insure having 0.5 ppm. of unreverted phosphate in the water at the ends of the system. Where dead ends are not troublesome or where the water is not excessively corrosive and protection of the consumers' equipment is not to be considered, a slightly lower residual would be effective.

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SOLUTION FEED CONTROL

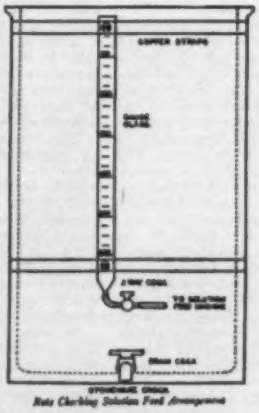
T. M. RIDDICK

Consulting Engr. and Chem.
New York City

WITHIN the past few years there has been a rapid increase in the use of solution feed equipment for pressure filters, and small water supplies with pumping rates of less than about 700 GPM. This trend now fills the long-felt need for apparatus of a capacity below that of standard dry feed machines or vacuum-type chlorinators. These feeders are of diaphragm or piston type and discharge roughly a maximum of 250 ml. per minute for single units, with duplex rating of approximately twice this figure. Experience with both plunger and diaphragm pumps, operating under a negative head, emphasizes the possibility of flow stoppage due to clogging of suction or discharge lines, loss of prime through air leakage, air binding, etc. If the machine is fed by a suction hose extending over the rim of the solution crock it is most inconvenient and difficult to judge at what rate the solution is being added, and whether the discharge is constant.

A new type of solution feed arrangement is shown in the accompanying drawing. It has been used with excellent success by the writer.

The crock illustrated is a fifty-five gallon stoneware pot of substantial construction. The draincock can be furnished as standard equipment and provides an easy way of drawing off sludge which will in time accumulate from commercial chemicals. Six inches above the center line of the draincock is placed a three-eighth inch three-way hard rubber cock and T. (See sketch.) This location prevents clogging of the feed line by sludge or chemicals which have not completely dissolved. (It is better to have this cock installed at the factory, since the hole may be drilled more readily at the shop than in the field.)



Rate Checking Solution Feed Arrangement

Rate Checking Solution Feed Arrangement

The gauge glass is made by drawing down one end of heavy-walled Pyrex tubing of 38 mm. diameter. The tube, as pictured, is calibrated at 25 ml. and number marked at 100 ml. intervals. However, it may be graduated at intervals of 10 ml. with no overcrowding of division lines. The gauge glass enables the operator to observe the height of solution in the crock without close inspection, and also affords a means for measuring the amount of solution used daily since the tube calibration may be interpreted in terms of gallons of crock capacity, or pounds of chlorine, alum, ferric-chloride, etc.

In order to ascertain the specific rate of feed, it is only necessary to turn the threeway cock 180 degrees. This causes the solution to be drawn from the gauge glass instead of from the crock, and by noting the time (in seconds) required for a drawdown of say 100 ml., or, by observing the drawndown in ml. for a period of one minute, the rate of discharge of the feed machine can be accurately established.

It also serves as a very ready method for determining whether or not the machine is feeding at all. For instance, clogging of the feed line often occurs when using chemicals shipped in burlap bags, due to small threads which pass into the crock when bags are emptied.

The gauge glass is held in place by two copper or monel straps, which secure it to the solution pot.

It is advisable to attach a high speed mixer to the crock to assist the operator to quickly and easily prepare solutions. When hypochlorites or ferric salts are used the shaft and propeller of the mixer should be coated with rubber or heavy bituminous enamel.

The cost of the equipment is negligible when considering the operating facilities afforded.

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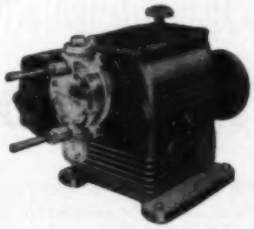

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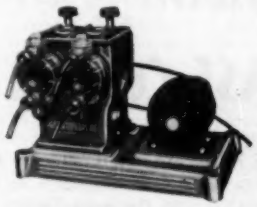

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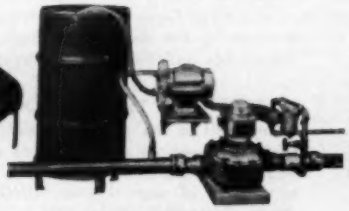

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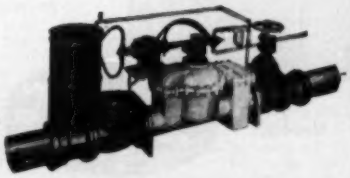
4-100 lbs./sq. in.



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CORROSION CONTROL BY THE USE OF LIME*

A Review of the Basic Principles of the Process

EDWARD S. HOPKINS
Associate Engineer
Bureau of Water Supply, Baltimore, Md.

IT is common knowledge that soft water containing dissolved oxygen and free carbon dioxide corrodes iron and steel pipe excessively. In accordance with the electrochemical theory, oxygen is the direct corroding agent with the *rate* governed by the reaction between the dissolved oxygen in the water and the film of atomic hydrogen at the surface of the metal[8]. It is also known that the hydrogen ion concentration of the water is not a factor in the initial deposit of rust on clean or bright iron surfaces, since the initial rate of deposition is about equal at pH values between 5.0 and 9.0. After the initial rust coating has been deposited, continued corrosion of the metal is in direct proportion to the porosity of this coating. Rust coatings deposited on pipe walls from waters containing "aggressive" carbon dioxide is porous while that laid down in alkaline waters is compact and dense[11]. Compact coatings of iron oxide or calcium carbonate, or a combination of both, will prevent diffusion of the dissolved oxygen in the water to the metal.

"Aggressive" carbon dioxide was the term employed by Tillmans[10] to describe the corrosive action of carbon dioxide dissolved in soft waters having low pH values. Massink and Heymann[6] demonstrated that the aggressiveness of the carbon dioxide is regulated by the total bicarbonate alkalinity and pH of the water. To measure the corrosivity of aggressive carbon dioxide bearing waters, von Heyer[5] developed the "marble test" now used as standard procedure.

Neutralization of aggressive carbon dioxide by alkali retards cold water corrosion by stoichiometric reaction and by the precipitation of the dense iron oxide-calcium carbonate coating on the pipe surface. It is, therefore, an indirect method of corrosion control. Lime or other alkali treatment will not *stop* corrosion unless the pH value is continually maintained at the calcium carbonate saturation point. The disappearance of "red water" is not necessarily a criterion of the elimination of corrosion, but does denote a reduction of corrosion.

The *rate* of corrosion in pipe lines is a function of the loss in dissolved oxygen from the water during passage through the system. A slight loss may be noted during corrective treatment, but an appreciable loss is noted when corrosion is occurring. Routine testing for dissolved oxygen is the best method for determining the extent and efficiency of any corrosion correction treatment.

Hot water corrosion, in relation to steam generation, is not eliminated by this treatment, since the bicarbonate ion is formed by the neutralization of the free carbon dioxide. Upon heating the water to boiling, the bicarbonate ion breaks down to free carbon dioxide and hydroxide, frequently producing corrosion in return condensate lines. Localized treatment at the steam generating plant is required to overcome this condition.

Treatment of Very Soft Waters

A soft water of less than 20 parts per million hardness, will have slight buffer action and maintenance of the calcium carbonate equilibrium through the addition of lime will require high pH values, resulting in caustic alkalinity. This is usually of minor importance to industry but may be objectionable to the taste in that it has a limy taste.

The Catskill water supply for New York City has a normal alkalinity of 8 parts per million. Hale[4] reports that neutralization of the free carbon dioxide in cold water with lime raised the pH value to between 9.7 and 9.9; with 10 parts per million excess calcium hydroxide the pH was 10.1; with 50 parts per million, 10.3-10.4 and with 100 parts per million it was 10.8. After 148 days, black iron pipe, ¾ inch in diameter, was heavily coated by a soft sludge of calcium carbonate. Flow decreased as follows:

Untreated water	—55 percent
CO_2 just neutralized	—35 percent
10 ppm. excess lime	—20 percent
20 ppm. excess lime	—15 percent
30 ppm. excess lime	—10 percent
40 ppm. excess lime	— 6 percent
50 ppm. excess lime	— 8 percent
100 ppm. excess lime	—16 percent

It may be concluded from the above data that high lime treatment is not practical for these soft waters without periodically flushing the system. With a gravity flow river water serving an industrial plant, this would not be expensive in comparison to the cost of pipe renewal. The introduction of substances to a very soft water to increase buffer action and lower the pH value necessary for corrosion control is not usually economically advantageous. Unless cheap water is available for flushing, replacement of corroded pipe is the most practical operation.

It is apparent, therefore, that lime treatment to eliminate corrosion has its greatest value with waters having a hardness greater than 25 parts per million.

Treatment Guides and Plant Control

Baylis[1] in 1922 initiated pH controlled corrective treatment with lime as a function of water purification, using the Gunpowder River supply at Baltimore, Md.

This water is moderately hard, having the following average analysis:

Alkalinity	— 35 parts per million
Soap hardness	— 38 parts per million
Bicarbonates	— 43 parts per million
Sulfates	—7.9 parts per million
Free carbon dioxide	— 6 parts per million
pH	—7.1 parts per million

To facilitate plant operation Baylis[2] studied the solubility of calcium carbonate under varying conditions of pH value and total alkalinity and prepared curves revealing the calcium carbonate saturation point under these various conditions. Fig. 1 reveals these values and serves as a practical guide. These curves show, for instance, that with a total alkalinity of 50 ppm. or less a pH of 8 or more is required to obtain calcium carbonate saturation.

Enslow[3] developed a continuous corrosion or stability indicator which keeps a constant flowing sample of water at the calcium carbonate saturation point. This device (Fig. 2), permits testing for the correct pH and alkalinity of the treated water as often as desired, and without laborious and time consuming operations. Usually a 4 hour contact period is given between the powdered calcium carbonate and the water passing through the unit. It is excellent for use with waters subject to changes in buffer characteristics. Any

*Excerpts from a paper presented before the Technical Association of the Pulp and Paper Industry. Printed by permission of the Association.

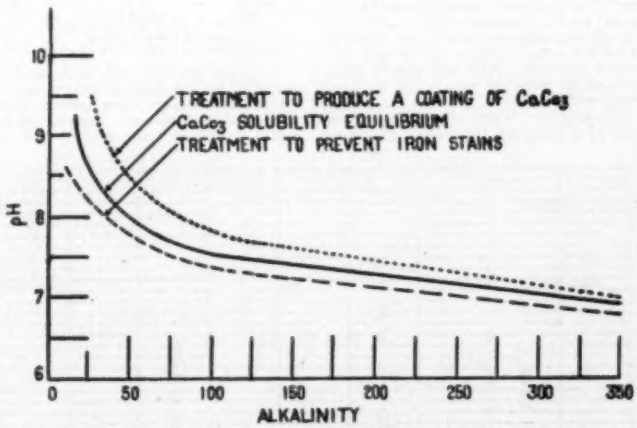

Fig. 1—Curves Revealing the Titratable Alkalinity and pH Values of Waters at the Calcium Carbonate Solubility Equilibrium Point, and the Sub-Saturation and Super-Saturation Points.

(In corrosion control the Carbonate Saturation Curve will shift downward for those waters which are naturally buffered. Note elsewhere in this article the pH and alkalinity found to apply in treatment of the Baltimore water—namely pH 7.8 at 38 ppm. of alkalinity.)

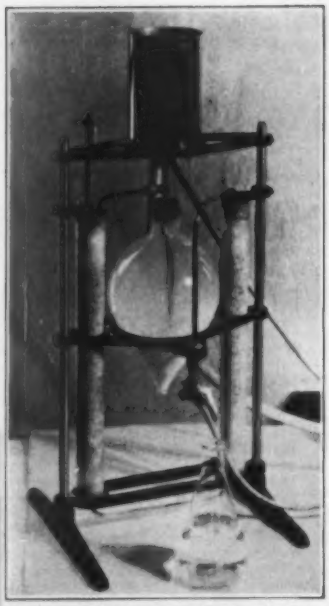

Fig. 2—The Enslow Continuous Corrosion and Stability Indicator.

(The well known "marble solubility test" adapted to continuous operation—the calcium carbonate saturation index being revealed by testing the water entering and leaving the Stability Indicator.)

necessity for treatment change is easily detected by sampling of the water before and after passage through the Enslow stabilizer, which serves as a continuous "marble test."

The value of corrective treatment with lime or other alkali rests upon the *constant* maintenance of the hydrogen ion concentration at the calcium carbonate saturation point in order to maintain a thin but dense protective film. It cannot be an intermittent treatment, since at any time the water is below this value aggressive carbon dioxide is present and will redissolve the coating previously precipitated.

Accurate control of the lime dosage and precise pH values can best be had by the use of recording potentiometers. These devices (Fig. 3), are usually actuated by glass electrodes with ranges in pH from 2.0 to 12.0. The charts used on the potentiometer (Fig. 4), serve as a permanent record of the pH value of the delivered water and history of treatment. This equipment is inexpensive and trained technical skill is not required to keep it in good order.

Commercial dry feeders and other appliances are available for the application of lime to a water supply. Either burned pebble lime or hydrated lime may be used. Large plants find burned lime the most economical, when continuous automatic slakers are utilized.

Results of Treatment

Once calcium carbonate equilibrium has been established, the water will remain stable and the effect of lime treatment is apparent in pipe lines after a few months. The calcium carbonate solubility point for the Gunpowder River water supply of Baltimore is at pH 7.8 with an alkalinity of 38 parts per million. It will be noted from the accompanying table that the pH value of the water is constant after passage through 1200 miles of distribution mains and an open balancing reservoir of 459 million gallons capacity. Since passage through these reservoirs may be considered analogous to a spray pond, it is apparent that corrective treatment with lime has value for industrial use.

The value of protective treatment with lime is illustrated in a recent American Water Works Association committee report[1] which states:

"Other factors being equal, the data show marked correlation between pH value of water carried, and rate of pipe line capacity loss. Average conditions reported indicate for supplies with a pH value of 6.5 twice the loss observed in supplies with a pH value of 8.0."

Other than causing a slight increase in hardness, corrective treatment with lime does not have a direct effect upon steam generation. Boiler water control is an independent function. However, warm water, 70° to 100° F., will be non-corrosive and treatment is a profitable undertaking.

Treatment Costs

By stoichiometric reaction, 1 part of carbon dioxide equals 1.275 parts of caustic lime and 1.903 parts of hydrated lime. Due to the buffer action of various waters, this direct relation does not exist when maintaining the calcium carbonate saturation point. For this reason it is not practical to compute the contemplated cost of treatment upon a direct ratio of carbon dioxide to lime.

The cost of corrective treatment of the Gunpowder River water has averaged 43.1 cents per million gallons over the past 25 years. This included labor, storage and depreciation. The 1947 cost was 35.9 cents per million.

Summary and Conclusions

The principles of the electro-chemical corrosion of iron and steel pipe by low alkalinity waters containing "aggressive" carbon dioxide have been reviewed.

The fixation of this carbon dioxide by the correct quantity of lime causes a dense, compact coating of calcium carbonate-ferric oxide to be deposited on the pipe walls. This coating, if of proper density, prevents the diffusion of the dissolved oxygen in the water to the hydrogen film on the iron, thereby retarding corrosion. Rust deposited when the water is below the calcium carbonate saturation point will permit diffusion of the dissolved oxygen and does not check corrosion.

The treatment is not satisfactory for very low alkaline waters (10 ppm. or less) since

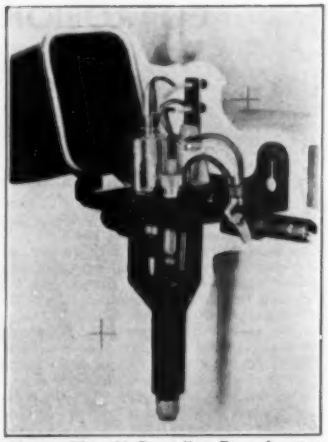

Fig. 3—The pH Recording Potentiometer. (So useful in regulating and controlling lime application in anti-corrosion treatment of waters if the optimum alkalinity—pH ratio is to be maintained.)

overly high pH values are required, depositing a soft fluffy sludge-like coating in the pipe lines. This sludge is porous and sometimes of sufficient magnitude to retard flow.

***pH of Samples From Distribution System**
(15 Year Average)

	Plant Effluent*	Distrib. System 1st Zone
January	7.8	7.6
February	7.8	7.6
March	7.8	7.7
April	7.8	7.7
May	7.8	7.7
June	7.7	7.7
July	7.7	7.7
August	7.8	7.7
September	8.1	8.0
October	8.5	8.2
November	8.2	8.1
December	7.7	7.6
Max. month	8.9	8.7
Min. month	7.0	7.0
Aver. month	7.9	7.8

*Samples collected every 2 hours.
**Samples collected weekly from 12 stations.

From what has been said, fairly accurate control of the lime application is necessary. For this purpose recording potentiometers serve a valuable purpose. Commercial dry feeders and slakers are desirable for the

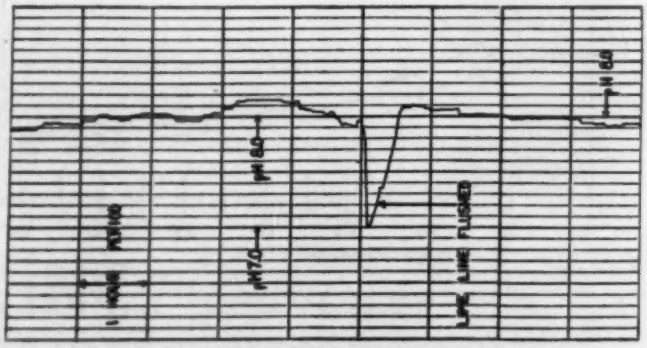

Fig. 4—A Specimen pH Chart Produced by the Recording Potentiometer. (During this period the attempt was to hold the lime treated water to a pH of 7.9 to 8.0)

most economical and effective application of lime in corrosion control.

A water maintained just at the calcium carbonate saturation point has a stable hydrogen ion concentration and the pH value is usually unchanged in passing through a distribution system.

There is an extensive investment in iron and steel pipe which needs protection against internal corrosion.

Even though complete elimination of corrosion may not be attained by lime treatment, the value of the reduction, where the water is fairly corrosive, greatly exceeds the cost of treatment. Based upon public water supply experience, it is believed that corrective treatment with lime will produce a water of considerable economic value to many industries[6].

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THERMAL CONDUCTIVITY OF INSULATING MATERIALS*

The measure of heat loss, sometimes called the k-factor, is given below. The *smaller* this constant is for a given material *the better the insulating properties* of the material.

Heating requirements are measured by engineers in "degree-days." Degree-days are published in heating handbooks and in United States Weather Bureau reports for nearly every city in the United States and Canada. One degree below 65 degrees F. for a 24-hour period equals 1 degree-day.

MATERIAL	DENSITY, lbs./cu. ft.	CONDUCTIVITY** (mean temp.) (90 deg. F.)
Air space between walls (3¼ in.)	.081	.86 to 1.10
Cotton	.65 to 6.25	.21 to .29
Pure wool	6.24	.26 to .32
Silk	6.24	.28 to .34
Hair felt	13.0	.26 ..
Flax fiber	13.0	.31 to .33
Cork, ground	8.1	.27 to .31
Sugarcane fibers	13.5	.34 ..
Pine wood	34.3	.8 to 1.0
Wood pulp board, plaster base	16.2	.3 to .4
Mineral wool	2 to 7	.27 to .30
Magnesia (85% magnesia, 15% asbestos)	13-16	.40 to .46
Expanded vermiculite	6 to 7	.33 to .43
Diatomite powder	10.6	.3 to .5
Diatomite blocks	28.1	.58 ..
Pumice gravel	18.8	.64 ..
Tile (clay and plaster)	12.7	.60 ..
Glass, plate	15.5	3.6 to 7.3
Bricks, dry	125.0	3.0 to 6.0
Brickwork (mortar bond)	132.0	4.0 to 5.0
Gypsum plaster	46.2	2.0 to 5.0
Concrete, 1-2-4	150.0	5.0 to 9.0
Slate shingles	162 to 205	10.0 to 10.4
Building stone	165.0	12.5 ..
Steel (1 percent carbon)	489.0	314.0 to 328.0
Copper (pure)	558.0	2,580.0 to 2,670.0
Silver (greatest conductivity)	655.0	2,860.0 to 2,920.0

*Authorities: National Bureau of Standards, Federal Housing Administration, and various university and research laboratories.

**Conductivity—British thermal units transmitted per hour per square foot of material 1 inch thick, per degree F. difference in temperature of the two faces.

WEIGHTS PER CUBIC FOOT OF DRY CHEMICALS USED IN WATER & SEWAGE WORKS

Chemical	Type	Weight per Cu. Ft.
Activated Alum	Ground	60 lbs.
Aluminum Sulphate	Powder	28 to 45 lbs.
	Ground	60 to 62 lbs.
	Lump	62 to 67 lbs.
Ammonium Aluminum Sulfate	Powder	58 to 62 lbs.
	Nut	60 to 64 lbs.
	Lump	64 to 68 lbs.
Black Alum	Ground	54 lbs.
Carbon (Activated)	Powder	*15 lbs.
Clay (Bentonite)	200 Mesh	50 lbs.
Copper Sulphate	Powder	64 lbs.
	Snow	85 lbs.
	Granular	90 lbs.
	Medium	80 lbs.
	Large	73 lbs.
Disodium Phosphate	Crystal	60 to 64 lbs.
	Anhyd. Powder	58 to 62 lbs.
	Flake	50 to 54 lbs.
Ferri-Floc		72 lbs.
Ferrisul*		72 lbs.
Ferrous Sulphate	Sugar Crystal	62 to 66 lbs.
Hydrated Lime	Powder	*40 to 45 lbs.
Potassium Aluminum Sulphate	Powder	58 to 62 lbs.
	Nut	60 to 64 lbs.
	Lump	64 to 68 lbs.
Quicklime	Lump	60 to 70 lbs.
	Pulverized	80 lbs.
Soda Ash 58%	Light	*35 lbs.
	Dense	65 lbs.
Sodium Aluminate	Powder	*40 to 50 lbs.
Sodium Bisulfite (Anhyd.)	Powder	72 to 76 lbs.
Sodium Fluoride	Special Light	*38 to 42 lbs.
	Light	48 to 52 lbs.
	Dense	67 to 75 lbs.
Sodium Sulfate	Crystal	58 to 64 lbs.
	Needle	46 to 52 lbs.
	Powder (Anhyd.)	78 to 86 lbs.
Sodium Sulfite	Powder (Anhyd.)	80 to 90 lbs.
Sodium Thiosulphate	Granular	59 to 63 lbs.
	Fine, Cryst.	63 to 71 lbs.
	Coarse, Cryst.	54 to 58 lbs.
Tri-Sodium Phosphate	Ground	59 to 63 lbs.
	Med., Cryst.	56 to 60 lbs.
	Coarse, Cryst.	54 to 58 lbs.

*Requires hopper agitation.
(Courtesy R. J. Leveque, Sales Mgr., Omega Machine Co.)

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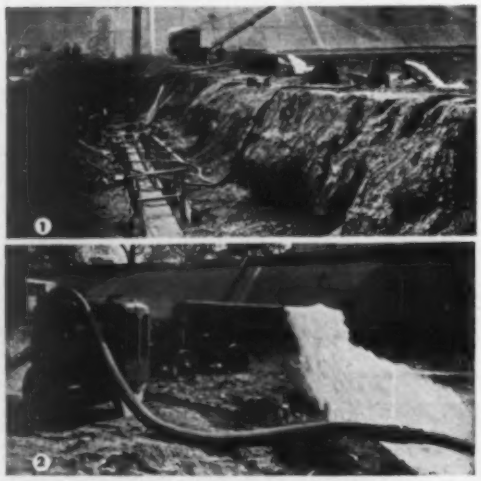
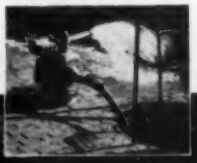
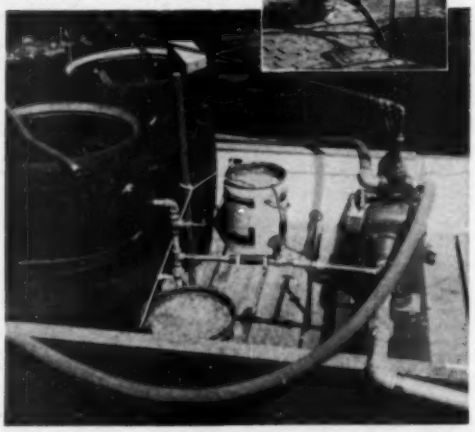


Above: Low cost dewatering. River bed excavation drained with suction hose and row of Jaeger pumps.

Dewatering pumps from 1½" portable aluminum "Bantam", for manhole pumping and small surface spraying outfits, up to 10" portables of 240,000 gph. capacity for largest excavations, by-passing sewers, big well point installations, etc. All models have doubly-sure fast priming effected by two independent, simultaneous actions, portable or stationary mounting. Pressure-type pumps available for jetting and supply pumping.

Right: Pumping manhole with Jaeger "Bantam". Below: Spraying for algae control. Courtesy Wisconsin State Board of Health.





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CONTROL OF MICRO-ORGANISMS AND AQUATIC VEGETATION

L. F. WARRICK
H. E. WIRTH AND W. VAN HORN*
Madison, Wisconsin

PUBLIC interest in clean waters has manifested itself in many ways in recent years. Pollution control agencies have been established in many states, and every session of Congress for the past decade has been called upon to consider legislation relating to this subject. Stream clean-up programs have been inaugurated. In rapidly increasing numbers municipalities have installed modern sewage treatment works. Industries have either proceeded or are being induced to develop and install methods for utilization or treatment and inoffensive disposal of pollutional wastes. The objective of all these efforts is to restore polluted water courses to proper sanitary conditions and to keep them as clean and attractive as possible.

The purpose in discussing the control of aquatic nuisances by chemical methods is to present another phase of the general problem of keeping waters clean and attractive, aside from treatment of sewage and trade wastes. The intent is to set forth, briefly, difficulties created by superabundant growths of algae, rooted weeds and certain obnoxious growths in lakes and streams, and to follow with a review of developments in overcoming some of these difficulties.

Algae may be popularly described as microscopic, one-celled plants produced in immense quantities in shallow water areas under favorable seasonal conditions. Growing in reservoirs, they achieve notoriety as the cause of nauseating tastes and odors in drinking water. The effectiveness of copper sulphate in suppression of algae growths has long been known, but there are certain important considerations involved which must be met in large-scale applications of such treatment to assure satisfactory results. It is also proposed to describe some of the studies that have been carried out under the general supervision of the Wisconsin Committee on Water Pollution through its Committee on Chemical Treatment of Lakes and Streams, with attention being called to methods for more definitely controlling dosages of chemical to prevent unnecessary damage to fish and other aquatic life, particularly fish foods.

General Problems

Under certain conditions, not well understood at present, algae multiply so rapidly that in a number of lakes and streams their presence gives the water a pea-soup color and consistency. These algae "blooms" naturally detract from the enjoyment of the waters by cottagers, bathers, boaters and fishermen because of the stench produced during the decomposition of such masses of algae. Similarly, many weed beds, heretofore ignored or regarded as desirable for the maintenance of good fish population, have become a nuisance and hindrance to the more popular recreational uses of lakes and the development of residential areas or summer resorts around bodies of water.

Rooted plants growing in abundance in recreational areas have caused much trouble for resort and other property owners. No one enjoys using a beach populated by a dense growth of weeds. Boating is difficult when weeds become wrapped around oars or propeller. Offensive odors result when the plants decompose after they have been cut and washed ashore, or have died in the fall.

One-Man-Power Barge
Applying copper-sulphate treatment to a shallow waterway to control odors from algae growth.

One of the Smaller Outfits for Copper Sulphate Spraying of Small Lakes

Some people are allergic to aquatic plants and develop rashes when they swim in certain weedy areas. Another problem, closely allied to allergy, is caused by a microorganism (*cercariae*), the effects of which are commonly referred to as "swimmer's itch." Outbreaks occurring in some bathing areas have annoyed and alarmed persons both directly and indirectly affected.

There is also an economic aspect that must be considered. The decreasing value of real estate bordering infested lakes is a direct loss to owners and eventually may have a serious effect on tax rolls. Industrial processes have been interfered with at times by algae growths, which have hampered production or caused loss through spoiling the product. For instance, paper mills have had objectionable odors imparted to paper and boxboard used for packaging foods and confections by large amounts of algae growing in the water supply used by the mills. There are instances on record where the death of cattle and other livestock has been attributed to the presence of algae in the drinking water. All of these conditions have resulted in efforts by property owners and others concerned to control these algae, weed and other growths considered aquatic nuisances.

Control Measures

Efforts to eliminate unwanted vegetation have generally utilized manual or mechanical methods. Under-water cutting machines have been made available for cutting rooted weeds. The manually-operated equipment consists of a ribbon steel saw which can be drawn back and forth across weedy areas in the manner of a lumberjack's saw. Power cutters mounted on barges, patterned after harvesting machinery, have been developed. Tractor or truck drawn cables have been used to remove littoral vegetation. (See WATER WORKS AND SEWERAGE for March, 1942—"The Control of Water Chestnut Growths.") Cut material must be collected and removed for burning, burial or disposal on land at isolated places. Otherwise, it will drift to shore, decompose and cause an odor nuisance. Dredging generally effects more lasting results than weed cutting because of removal of the roots.

At best, all of these are laborious, time-consuming methods. They are effective in solving only a part of the general problem of aquatic nuisance control. They do not take care of troubles caused by excessive growths of algae or small free-floating plants.

Early Studies:

Investigations of chemical treatment were started at an early date to devise practical procedure for taking care of all phases

*Chief Engineer, Assistant Sanitary Engineer and Assistant Biologist, respectively, of the Wisconsin State Department of Health.

of the problem. Tastes and odors in water supplies having been identified with growths of algae more than sixty years ago, attempts were first directed to overcoming this difficulty. Studies were undertaken by the Bureau of Plant Industry, U. S. Department of Agriculture, in cooperation with the Massachusetts State Board of Health, and in 1901 Moore[1] successfully worked out a procedure for destroying algae with small quantities of copper sulphate. Further studies of the application of this method were reported in 1904 by Caird[2] at Elmira, N. Y., Carroll[3] at Butte,

"Stern Wheeler"

This barge, for the control of both algae and rooted weeds, is used by a Sanitary District set up by a Wisconsin town for the primary purpose of applying preventive treatment in the control of aquatic nuisances.

Mont., and Fletcher[4] at Hanover, N. H. Results of the treatment of the reservoir of the Winchester, Ky., water supply were reported in 1905 by Moore and Kellerman[5]. Additional information was presented by Moore and others[6] during the same year in a symposium conducted by the New England Water Works Association. Prince[7], Caird[8], Kellerman[9], Huff and House[10], Hale[11] and others have added much to the knowledge on this subject following this early work. Ample experience has been gained to date to definitely establish the role of copper sulphate treatment in the control of algal tastes and odors in water works practice.

Chemical suppression of unsightly and ill-smelling algae scums, as a nuisance control measure in lakes and streams used for recreational purposes, has largely developed during the last two decades. A pioneering study in this field was conducted by Alvord[12] at Madison, Wis., who recommended in 1920 that copper sulphate be applied, under competent supervision, in sufficient amounts to maintain the lake waters in question in a clean and attractive condition. Experiments were continued for the next few years by the city and the University of Wisconsin, but it was not until 1925 that suitable procedures and equipment had been devised to carry out an effective treatment program.

Domagalla[13] has described the spraying facilities found most satisfactory, consisting essentially of a solution tank for copper sulphate and a power sprayer mounted on a scow. Use of this equipment supplanted the original practice of dragging burlap bags of the chemical behind a boat, with both more efficient and economical results. Domagalla also mentions his use of arsenical compounds for destruction of a variety of water weeds. In continuing work on the lakes at Madison and elsewhere up to the present he has further improved the technique of treatment and done much toward placing the control of aquatic nuisances on a sound basis.

Regulatory Measures

It has been inevitable that controversy would arise regarding the placing of chemicals like copper sulphate in waters frequented by fishermen. There have occurred certain instances where misguided enthusiasts, working on the theory "if a little does good, more should do better," have destroyed fish. These mistakes have resulted in demands that all practices of chemical treatment of this nature be prohibited or there be inaugurated adequate regulatory measures.

In Wisconsin, as a result of executive order, a committee was established in 1938 to review the whole problem of algae and weed control and recommend suitable policies and procedures of administration. It was finally determined that the work should be carried out on a continuing basis as one of the functions of the State Committee on Water Pollution, a statutory agency vested with broad powers for controlling pollution.

The 1941 legislature passed an act calling upon the Committee on Water Pollution: "To supervise chemical treatment of waters for the suppression of algae, aquatic weeds, swimmers' itch and other nuisance-producing plants and organisms." To this end the committee may conduct experiments for the purpose of ascertaining the best methods of such control. It may purchase equipment and may make a charge for the use of the same and for materials furnished, together with a per diem charge for any services performed in such work. The charge shall be sufficient to reimburse the committee for the use of the equipment, the actual cost of the materials furnished, and the actual cost of the services rendered plus 10 per cent for overhead and development work. The legislature also passed an amendment to the Town Sanitary District Act authorizing the control of aquatic nuisances by a Sanitary District and providing means for financing such measures.

The Wisconsin Committee on Chemical Treatment of Lakes and Streams consists of an attorney of the Wisconsin Public Service Commission; the chief biologist of the State Conservation Department; the chief chemist of the State Laboratory of Hygiene; and the State Sanitary Engineer of the State Board of Health. Its principal activities have been to obtain all facts available on chemical treatment, institute research to determine procedures to prevent unnecessary damage to fish and fish foods, and establish supervisory control over treatments so that chemicals would be scientifically applied rather than promiscuously used in the waters of the state. Laboratory and field investigations have been carried out with the aid of both special personnel and technical staffs of departments concerned.

The committee studied the effect of chemicals employed on various species and sizes of fish and some of their food material to determine toxic concentrations. Some of the results obtained are mentioned later. Spraying devices were tested and improved, dusting and broadcasting equipment for spreading chemicals was tried, and various other facilities to aid in obtaining reasonably good control over dosages have been studied. The biological laboratories at state fish hatcheries, and facilities at the University of Wisconsin were made available for this work. The committee has also developed a permit system in the supervision of treatment activities.

Apparatus and Treatment Procedure

During the summer of 1939 the Committee on Chemical Treatment of Lakes and Streams authorized treatment and special studies of several lakes in the state using copper sulphate in order to suppress objectionable algae growths. The first treatments were made with improvised apparatus which was largely of an experimental nature and was later changed somewhat to provide a more convenient means of treatment. A 50-gallon wooden barrel having a partition extending from the top to within six inches of the bottom was used as a solution box. Copper sulphate crystals of approximately pea size were placed in the barrel and hot water from the cooling system of the boat engine discharged into the barrel on one side of the partition. This liquid then passed downward under the partition and into the copper sulphate crystals and upon reaching the other side of the partition was practically saturated with copper sulphate.

A motor-driven portable pump was obtained and placed in the boat for the purpose of spraying the copper sulphate solution. Water was drawn from the lake and a small amount of the concentrated copper sulphate solution was introduced into the suction side of the pump. In passage through the pump the solution mixed with a comparatively large amount of lake water before being discharged through two 1-inch rubber hoses equipped with nozzles which were manually operated to spray the dilute copper sulphate solution onto the surface of the lake.

The first treatments were controlled by varying the speed of the boat and the amount of copper sulphate crystals placed in the solution barrel. It was found that this method would dissolve approximately 200 pounds of copper sulphate per hour. Later developments and refinements in the treatment process included the construction of a speedometer which gave an accurate measurement of the speed of the boat and also the installation of a small Venturi meter which measured the amount of copper sulphate solution being discharged into the suction side of the pump. Later another baffle was placed in the solution barrel and it was found that it was possible to obtain a saturated solution of copper sulphate which did not vary appreciably in strength.

Tables were also made, indicating the amount of copper sulphate necessary for the treatment of a given body of water and

it was found that the most satisfactory method of controlling variables was by changing the volume of saturated copper sulphate solution fed into the system. In this way the concentration of copper sulphate sprayed onto the surface of the water could be varied in proportion to the speed of the boat so that the resulting concentration in the lake water could be maintained at any desired figure. In hard-water lakes the usual amount of copper sulphate added was equivalent to 1 p.p.m. in the top four feet of water. At the present time the apparatus is being further developed by the construction of a portable photolometer with which the concentration of copper sulphate solution can be accurately checked.

It has been found that one of the most essential steps in treating a lake to suppress algae growths is a survey to determine the concentrations of algae, the areas of the lake which can be most beneficially treated, the hardness and other characteristics of the water, the depth of water, and type of algae present. With this information it is possible to accurately estimate the amount of copper sulphate needed and the areas which should be treated.

At the present time the Committee on Chemical Treatment of Lakes and Streams has apparatus available for the treatment of such lakes which can be used on a rental basis by any interested party under direct supervision of representatives of the Committee. The Committee furnishes supervision of such treatment in order that satisfactory control over the amounts of copper sulphate can be maintained. A charge is made to lake improvement associations and other groups sponsoring the work. The program has been quite successful in reducing nuisances from prolific algae growths and has not appeared to be harmful to fish life.

Toxicity of Copper Sulphate to Fish and Fish Food

Numerous tests have been made to determine the copper sulphate dosage required to kill fish. The relation between alkalinity and toxicity of this chemical to fish was shown by experiment under controlled conditions in aquaria, measured in time required to cause death. The relative toxicity of 25 p.p.m. copper sulphate to brown trout fry varied inversely with the alkalinity. With 6 p.p.m. of alkalinity in the water, all fish died in 2.5 hours; with 248 p.p.m. alkalinity there were four survivors after 12.5 hours.

The large discrepancy between the accepted toxic dose for bass (2.1 p.p.m.) and that found in recent studies (160 p.p.m. or more), was explained as follows: The toxic dose of copper sulphate for several species of fish (black bass, yellow perch, sunfish, and bullheads) was determined in distilled water. The values so obtained agree well with those appearing in the literature. Thus, the conclusion must be drawn that the tests of previous investigators had been made in either distilled water or in very soft waters.

Chemical examination of hard water treated with copper sulphate disclosed the fact that the calcium carbonates and bicarbonates react with the copper sulphate producing insoluble basic copper carbonate, which in hard water was shown to be non-injurious to fish. The rate of removal of the copper from solution as a relatively harmless precipitate is not, however, an instantaneous reaction. Several attempts were made without very reliable results to fix exactly the actual rate of removal. In general, however, it was found that the majority of the copper is removed from solution in about one-half hour.

The fish used in the above tests were less than one year old and averaged about 4 inches in length. In order to ascertain whether very young fish were extremely sensitive to the chemical, a test was made with bass fry one and one-half months old and averaging one inch in length. Again the mineral matter of the hard water offered a protective action and these fish were not affected until a concentration of 80 p.p.m. was reached. The results indicate that the young fish are more susceptible than older ones, but that there is still a large margin of safety present between dosages which destroy micro-organisms and those which will kill young fish.

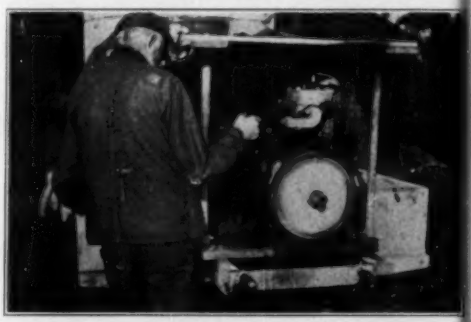
Results of the fish studies with various concentrations of copper sulphate have indicated: (1) The toxic doses of copper sulphate recorded in the literature for the various species of fish are correct only for distilled or very soft waters. (2) The mineral salts of hard waters remove copper from solution as an insoluble precipitate, thus increasing the amount of chemical which may be added before fish are killed. (3) The fatal dose for young large mouth black bass in hard water is 80 p.p.m.; for larger bass approximately 160 p.p.m. (4) Very short exposures of fish to high concentrations of copper sulphate produce high mortality.

Survival of Fish Food Animals in the Presence of Copper Sulphate:

A most important question concerns the effect of copper sulphate on animals other than fish; are certain kinds eliminated from a lake or so diminished as to reduce the fish food supply? A number of experiments undertaken on certain type organisms in various concentrations of copper sulphate showed the following: Rotifers survive low concentrations but were killed in concentrations ranging from 15 to 1,000 p.p.m. within a 30-hour period. Cyclops survived 4 to 15 p.p.m. concentrations for 88 hours, the length of the test. The common flat worm was found sensitive to a fairly low concentration of copper sulphate. All were dead within 24 hours in concentrations of 10 to 50 p.p.m. Amphipods proved to be very sensitive, even to low concentrations, and undoubtedly are reduced in numbers when lakes are given copper sulphate treatment. Species that proved to be very resistant to copper sulphate included the isopods, damsel fly nymphs, water beetle larvae, and caddis fly larvae. In general, experiments and field observations have indicated that most animal organisms are far more resistant to low concentrations than are the several species of nuisance algae. Therefore, the animal organism population will not be seriously reduced or permanently damaged by the methods now in use for controlling algae nuisances.

Relation Between Algal Density and Copper Sulphate Dosage

An experiment was set up to obtain some idea of the rate at which typical algal cells absorb copper from solution. Living plants of *Microcystis* were placed in water of 154 p.p.m. alkalinity in a 5-gallon aquarium. Copper sulphate was added to make a 2 p.p.m. solution. Samples for copper determination were then taken at intervals. The conclusion was that "the amount of copper removed from solution by *Microcystis* is extremely small." Hence, for the control of this organism it appears it should not be necessary to increase the concentration of copper sulphate above 1 p.p.m. when treating lakes which have passed into an advanced bloom stage.



A Trailer Unit
Motor powered spraying outfit for lake treatment mounted on a trailer.

Swimmer's Itch

In the matter of "swimmer's itch," tests have shown the possibility of control of this difficulty by chemical treatment under certain circumstances, and accordingly the committee has been giving consideration to control of this nuisance as one important phase of its activities.

The most serious aspect of "swimmer's itch" probably is its detrimental effect on resort business. So far as has been determined, all cases of this type of skin irritation that have occurred in Wisconsin can be attributed to a single cause; namely, the accidental penetration into man's skin of the larvae of schistosome flukes (flatworms). These larvae, having developed in snails, emerge into the water where they will die unless they encounter the proper bird or mammal in which to complete their development. The infested birds and mammals in turn scatter eggs of the worm, which hatch and undergo development when they enter the snails.

This knowledge of the life cycle of the organisms causing "swimmer's itch" (more exactly termed schistosome dermatitis) is important because it suggests possible points of attack in

attempts to control the disease. Since the presence of this disease is of some economic importance to the state, studies have been carried out with the object of determining possible methods of controlling or combating the condition. The more important facts that have been learned to date will be presented here. A more extensive account of the researches subatantiating the statements made have been published by Brackett (see References 14-19 inclusive).

Investigations in Wisconsin during the summer of 1938 and reliable accounts of the occurrence of this disease in earlier years indicate that, with the exception of a few localities, only a relatively small number of individuals are ordinarily affected. With such being the case, it is obvious that control measures that are at all extensive or expensive cannot usually be justified. In these places, where other control methods are impracticable, it may prove helpful to bathers if they rub themselves briskly and thoroughly with a towel immediately upon coming from possibly infected water and before the water has time to be removed from the skin by evaporation. Apparently most of the larvae penetrate while evaporation is taking place in the thin film of water covering the body. The rubbing crushes them while they are still on the surface of the skin before they have penetrated.

Particular attention is called to this prophylactic measure because it is simple, costs nothing, and puts the responsibility directly on the persons concerned. Likewise it is a procedure that can always be used anywhere, regardless of varying environmental conditions, a fact which is not true of other control measures to be discussed. At present the possibility of controlling the parasite during the mammal phase of its cycle is remote. Methods designed only to kill the larvae in the water would be temporary since the snails may shed great numbers of the larvae for a period of several weeks.

Chemical Solution Tanks and Power Spraying Unit in a Barge

Dosages are controlled by regulating strength of chemical solutions and varying speed of barge travel indicated by a pendulum speedometer. Dosages are checked at intervals by colorimetric tests.

To eliminate the host snails, involved in outbreaks of "swimmer's itch," is undoubtedly the most effective and permanent method of preventing this annoying condition. It is evident from the absolute essentiality of snails in the life cycle of this parasite that the snail stage is a vital point of attack. The bulk of the studies have therefore been made on snails and their relationship to the disease. Amounts of copper carbonate as small as 3 lbs. per thousand square feet of bottom area have been used to kill the snails.

Rooted Weed Control

The elimination of rooted weeds involves the use of sodium arsenite which is a more dangerous chemical than copper sulplate. Arsenical compounds are considered as poisons. A dilute solution is sprayed onto the surface of the water over the plants. The plant is killed by the arsenic absorbed through the leaves and carried to the roots. The dosage depends on the weeds to be destroyed. The treatment is permanent until the area is reseeded. Experiments showed that fish (bluegills) can live at least six days in a solution that contains sufficient arsenic to kill plants. Further research showed that large mouth bass survived 232 hours in the presence of 6 p.p.m. Survival of 87 per cent was had in a 10 p.p.m. solution. Croppies and bluegills were unable to stand a 15 p.p.m. solution of arsenic.

During the summers of 1940 and 1941 the Committee on the Chemical Treatment of Lakes and Streams conducted a series of experiments in order to determine the practicability of using "Benochlor" products for the eradication of rooted aquatic weeds in the state of Wisconsin. Three Benochlor preparations used were Benochlor 3, Benochlor 3 T.D., and Benochlor 3 Special.

The following results were submitted as a progress report. Twenty-four test areas were set up in six bodies of water, some area being enclosed by a canvas fence supported by net floats and weights at the bottom to hold the fence in place. This permitted a definite control of the area treated.

In no cases were very promising results obtained with Benochlor 3.

In concentrations as low as 100 p.p.m. Benochlor 3 T.D. was effective in killing *Vallisneria, Potamogeton, Anacharis, Chara,* and *Myriophyllum* within 20 days. Further investigations will be made to determine the most desirable concentration to use.

In concentrations as low as 40 p.p.m., Benochlor 3 Special was effective in killing *Anacharis, Potamogeton, Zannichellis, Myriophyllum* and *Vallisneria* in 15 days. For Benochlor 3 Special or Benochlor 3 T.D. the weeds mentioned as being killed were the only ones present in the treated areas. These investigations did not determine the toxicity of these compounds to aquatic fauna.

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FORECASTING RESERVOIR SHORELINE EROSION

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THE concept of erosion by wave action, as indicated in Fig. 1, was used to prepare the accompanying chart. This chart (Fig. 2) was prepared for a particular case to aid in forecasting the probable limits of short erosion around a reservoir. Such forecasts are desirable to assist in fixing the severance lines for land acquisition, so that the lines will clear the erosion and inundation zones.

The case is a proposed reservoir on the San Jacinto River of Texas which is to furnish part of the water supply for Houston. The site lies within the West Gulf Coastal Plain and in that part known as the coast prairie, an area immediately fringing the Gulf in a strip of practically level prairie land extending inland 50 to 75 miles. The formation is of comparatively recent geologic time.

This plain has numerous consequent streams cutting across it, and the San Jacinto River is one of them. Characteristically, the larger perennial streams of this type have excavated comparatively deep channels in the coast prairie; their channels consist of two parts, a wide flood plain and a narrow and deeper low flow channel eroded therein. The side slopes extending upward from the flood plain to

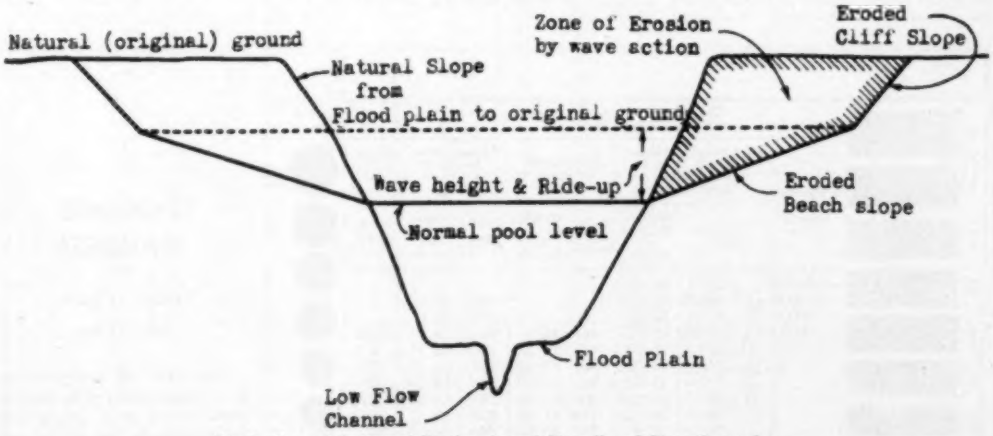


Fig. 1—General Pattern of Erosion Around Shore-line of River Reservoirs.

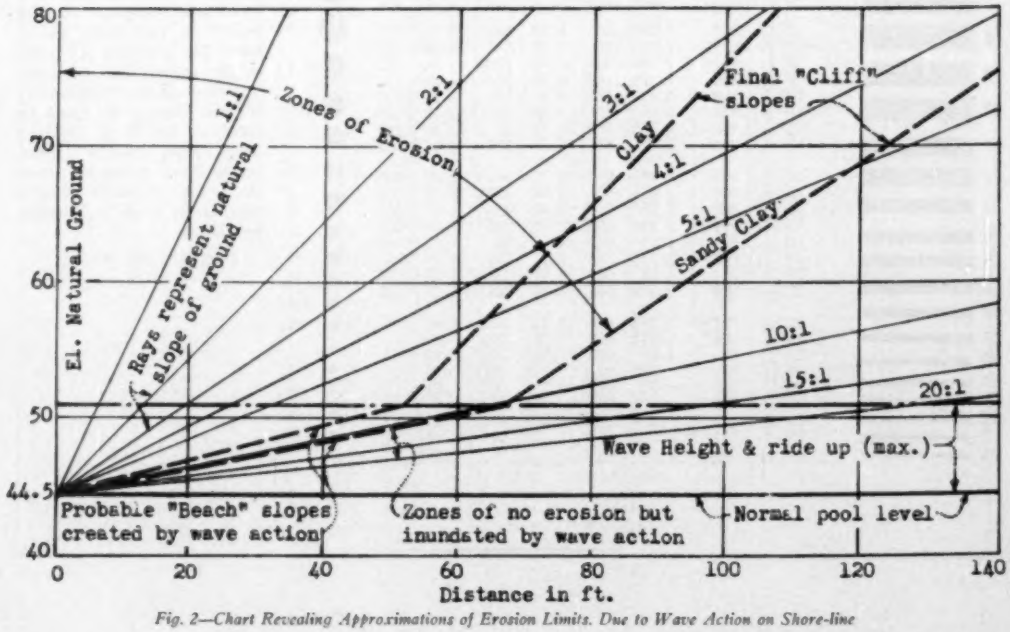


Fig. 2—Chart Revealing Approximations of Erosion Limits. Due to Wave Action on Shore-line

the prairie land are generally steep; between and near the confluences of tributaries they are as flat as 20 to 1. They are easily eroded by wave action.

The reservoir under consideration will be about 25 miles in length, averaging 1½ miles in width and with a flood plain depth of about 25 feet at the lower end. The normal pool level is fixed at elevation 44.5 feet. The adjoining prairie land has an elevation of 55 to 70 feet. During the spring months the reservoir will be subjected to frequent winds of the order of 35 miles an hour for a duration of a day or more, and with a single month's average of about 15 mph. Occasional tropical disturbances reaching the Texas coast are likely to have hurricane wind velocities of 100 mph. or more for periods of short duration. Hurricane winds of sustained velocities greater than 60 mph. for periods of several hours, have been experienced.

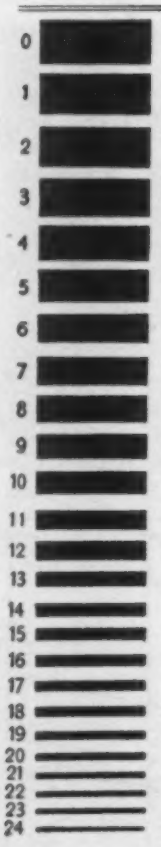
In the chart (Fig. 2) the ordinates represent the elevations of the adjoining higher land and the abscissa the distance from the rim of the pool when it is first filled. The rays on the chart represent the natural slope between the flood plain and the higher adjoining land. The heavy dashed lines represent the approximations of the probable effect of erosion for different types of soil; these were drawn by judgment after observing the effect of wave action for existing conditions nearby.

The wave-heights and ride-up were computed by the Stevenson equation as modified by Gaillard. Wave heights computed by this equation are found to fairly closely check with the observed wave heights on a small reservoir in the same vicinity. The observations were made during a hurricane with a wind velocity of 100 mph.

How to Use the Chart

As an example of how the chart is used is the following: Assume that elevations of the higher land above the flood plain are El. 60, the slope between them is 1:1 and the soil is within the classification of clay. Then the expected limit of erosion is at the intersection of the clay line and ordinate line 60, about 70 feet from the original pool's edge. The eroded area is represented by that part of the chart enclosed by the 1:1 ray and clay lines, and the ordinate line of El. 60.

As another example, assume that the natural slope is 20:1: Since this is less than the indicated beach slope, no erosion will occur. Instead, the land will be inundated by wave action to a point where ray 20:1 intersects the ordinate for the wave height plus ride-up—namely, about 130 feet from the normal water's edge.



Number of Gauge	U.S. Standard Gauge Adopted by U. S. Government July 1, 1893 — Thickness, Inches	U.S. Standard Gauge — Weight, Pounds per Sq. Ft.	Birmingham or Stubs' Gauge — Thickness, Inches	Birmingham or Stubs' Gauge — Weight, Pounds per Sq. Ft.	American or Brown & Sharpe's Gauge — Thickness, Inches	American or Brown & Sharpe's Gauge — Weight, Pounds per Sq. Ft.	Washburn & Moen Gauge — Thickness, Inches
0000000	½ .5000	20.4	.....	.....	.....	.....	.....
000000	15/32 .46875	19.125	.....	.....	580	23 6	.....
00000	7/16 .4375	17.85	.....	.....	5165	21 0	.....
0000	13/32 .40625	16.575	.454	18.5	.46	18.71	.3938
000	3/8 .375	15.30	.425	17 28	.409	16.71	.....
00	11/32 .343	14.025	.38	15 45	364	14 88	.331
0	5/16 .312	12.75	.34	13 82	324	13 26	.307
1	9/32 .281	11.475	.30	12 20	289	11 80	.283
2	17/64 .265	10.837	.284	11 55	257	10.51	.263
3	¼ .25	10.2	.259	10.53	229	9.36	244
4	15/64 .234	9.562	.238	9.68	204	8.34	225
5	7/32 .218	8.925	.22	8.95	181	7.42	207
6	13/64 .203	8.287	.203	8.25	162	6.61	192
7	3/16 .187	7.65	.18	7.32	144	5.89	177
8	11/64 .171	7.012	.165	6.71	128	5.24	162
9	5/32 .156	6.375	.148	6.02	114	4 67	148
10	9/64 .140	5.737	.134	5.45	101	4.16	135
11	⅛ .125	5.1	.12	4.88	09	3.70	120
12	7/64 .109	4.462	.109	4.43	08	3.30	105
13	3/32 .093	3.825	.095	3.86	.072	2.94	092
14	5/64 .078	3.187	.083	3.37	.064	2.62	.080
15	9/128 .070	2.868	.072	2.93	.057	2.33	.072
16	1/16 .062	2.55	.065	2.64	.05	2.07	063
17	7/128 .056	2.295	.058	2.36	.045	1.85	054
18	1/20 .05	2.04	.049	1.99	.04	1.64	.047
19	9/256 .043	1.785	.042	1.71	.035	1.46	.041
20	1/32 .037	1.53	.035	1.42	.032	1.31	.035
21	7/256 .034	1.402	.032	1.30	.028	1.16	.032
22	1/36 .031	1.275	.028	1.14	.025	1.03	.....
23	5/256 .028	1.147	.025	1.02	.022	.922	.....
24	1/40 .025	1.02	.022	.895	.020	.82	.....
25	9/512 .021	.892	.02	.813	.017	.73	.....
26	1/48 .018	.765	.018	.732	.015	.649	.....
27	7/512 .017	.701	.016	.651	.014	.579	.....
28	1/56 .015	.637	.014	.569	.012	.514	.....
29	5/512 .014	.573	.013	.....	.011	.461	.....
30	1/64 .012	.51	.012	.....	.01	.408	.....

STANDARD GAUGES*

Sheets, Plates and Wire

Sheet mills roll steel sheets to U. S. gauge unless otherwise ordered. Plate mills usually roll heavy plates, 3/16 and heavier, and light plate No. 8 to No. 12, to Birmingham gauge. In figuring weights of steel plates add to above the allowance for overweight, adopted by Association American Steel Manufacturers. All steel sheets in our *stock are rolled to the U. S. Standard Gauge. Brass is rolled to thickness by Brown & Sharpe's American Gauge. Copper is rolled to thickness by Stubs' or Birmingham Gauge.

* From Link-Belt Catalog.

AREAS OF CIRCLES—SQUARES—SQUARE ROOTS

(Also Fractions to Decimal Equivalent.)

No. N Fraction	Decimal	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
1/16	.0625	.0039	.2500	.0031
1/8	.125	.0156	.3536	.0125
3/16	.1875	.0352	.4330	.0276
1/4	.25	.0625	.5000	.0491
5/16	.3125	.0977	.5590	.0767
3/8	.375	.1406	.6124	.1105
7/16	.4375	.1914	.6614	.1503
1/2	.50	.2500	.7071	.1964
9/16	.5625	.3164	.7500	.2485
5/8	.625	.3906	.7906	.3068
11/16	.6875	.4727	.8297	.3712
3/4	.75	.5625	.8660	.4418
13/16	.8125	.6602	.9014	.5185
7/8	.875	.7656	.9354	.6013
15/16	.9375	.8789	.9683	.6903
1	1.	1.000	1.000	.7854
1 1/8	1.125	1.266	1.061	.9940
1 1/4	1.25	1.563	1.118	1.227
1 3/8	1.375	1.891	1.175	1.485
1 1/2	1.50	2.250	1.225	1.767
1 5/8	1.625	2.641	1.275	2.074
1 3/4	1.75	3.063	1.323	2.405
1 7/8	1.875	3.516	1.369	2.761
2	2.	4.000	1.414	3.142
2 1/8	2.125	4.516	1.458	3.547
2 1/4	2.25	5.063	1.500	3.976
2 3/8	2.375	5.641	1.541	4.430
2 1/2	2.50	6.250	1.581	4.909
2 5/8	2.625	6.891	1.620	5.412
2 3/4	2.75	7.563	1.658	5.940
2 7/8	2.875	8.266	1.696	6.492
3	3.	9.000	1.732	7.069
3 1/8	3.125	9.766	1.768	7.670
3 1/4	3.25	10.56	1.803	8.296
3 3/8	3.375	11.39	1.837	8.946
3 1/2	3.50	12.25	1.871	9.621
3 5/8	3.625	13.14	1.904	10.32
3 3/4	3.75	14.06	1.937	11.04
3 7/8	3.875	15.02	1.969	11.79
4	4.	16.00	2.000	12.57
4 1/8	4.125	17.02	2.031	13.36
4 1/4	4.25	18.06	2.062	14.19
4 3/8	4.375	19.14	2.092	15.03
4 1/2	4.50	20.25	2.121	15.90
4 5/8	4.625	21.39	2.151	16.80
4 3/4	4.73	22.56	2.180	17.72
4 7/8	4.875	23.77	2.208	18.67
5	5.00	25.00	2.236	19.64
5 1/4	5.25	27.56	2.291	21.65
5 1/2	5.50	30.25	2.345	23.76
5 3/4	5.75	33.06	2.398	25.97
6	6.	36.00	2.450	28.27
6 1/4	6.25	39.06	2.500	30.68
6 1/2	6.50	42.25	2.550	33.18
6 3/4	6.75	45.56	2.598	35.78
7	7.	49.00	2.646	38.48
7 1/4	7.25	52.56	2.693	41.28
7 1/2	7.50	56.25	2.739	44.18
7 3/4	7.75	60.06	2.784	47.17
8	8.00	64.00	2.828	50.27
8 1/4	8.25	68.06	2.872	53.46
8 1/2	8.50	72.25	2.916	56.75
8 3/4	8.75	76.56	2.958	60.13
9	9.00	81.00	3.000	63.62
9 1/4	9.25	85.56	3.041	67.20
9 1/2	9.50	90.25	3.082	70.88
9 3/4	9.75	95.06	3.123	74.66

No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
10	100	3.162	78.54
11	121	3.317	95.03
12	144	3.464	113.1
13	169	3.606	132.7
14	196	3.742	153.9
15	225	3.873	176.7
16	256	4.000	201.1
17	289	4.123	227.0
18	324	4.243	254.5
19	361	4.359	283.5
20	400	4.472	314.2
21	441	4.583	346.4
22	484	4.690	380.1
23	529	4.796	415.5
24	576	4.899	452.4
25	625	5.000	490.9
26	676	5.099	530.9
27	729	5.196	572.6
28	784	5.292	615.8
29	841	5.385	660.5
30	900	5.477	706.9
31	961	5.568	754.8
32	1024	5.657	804.2
33	1089	5.745	855.3
34	1156	5.831	907.9
35	1225	5.916	962.1
36	1296	6.000	1017.9
37	1369	6.083	1075.2
38	1444	6.164	1134.1
39	1521	6.245	1194.6
40	1600	6.325	1256.7
41	1681	6.403	1320.3
42	1764	6.481	1385.4
43	1849	6.557	1452.2
44	1936	6.633	1520.5
45	2025	6.708	1590.4
46	2116	6.782	1661.9
47	2209	6.856	1734.9
48	2304	6.928	1809.6
49	2401	7.000	1885.7
50	2500	7.071	1936.5
51	2601	7.141	2042.8
52	2704	7.211	2123.7
53	2809	7.280	2206.2
54	2916	7.349	2290.2
55	3025	7.416	2375.8
56	3136	7.483	2463.0
57	3249	7.500	2551.8
58	3364	7.616	2642.1
59	3481	7.681	2734.0
60	3600	7.746	2827.4
61	3721	7.810	2922.5
62	3844	7.874	3019.1
63	3969	7.937	3117.2
64	4096	8.000	3217.0
65	4225	8.062	3318.3
66	4356	8.124	3421.2
67	4489	8.185	3525.7
68	4624	8.246	3631.7
69	4761	8.307	3739.3
70	4900	8.367	3848.5
71	5041	8.426	3959.2
72	5184	8.485	4071.5
73	5329	8.544	4185.4
74	5476	8.602	4300.8
75	5625	8.660	4417.9

No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
76	5776	8.718	4536.5
77	5929	8.775	4656.6
78	6084	8.832	4778.4
79	6241	8.888	4901.7
80	6400	8.944	5026.5
81	6561	9.000	5153.0
82	6724	9.055	5281.0
83	6889	9.110	5410.6
84	7056	9.165	5541.8
85	7225	9.220	5674.5
86	7396	9.274	5808.8
87	7569	9.327	5944.7
88	7744	9.381	6082.1
89	7921	9.434	6221.1
90	8100	9.487	6361.7
91	8281	9.539	6503.9
92	8464	9.592	6647.6
93	8649	9.644	6792.9
94	8836	9.695	6939.8
95	9025	9.747	7088.2
96	9216	9.798	7238.2
97	9409	9.849	7389.8
98	9604	9.900	7543.0
99	9801	9.950	7697.7
100	10000	10.00	7854.0
101	10201	10.05	8011.9
102	10404	10.10	8171.3
103	10609	10.15	8332.3
104	10816	10.20	8494.9
105	11025	10.25	8659.0
106	11236	10.30	8824.7
107	11449	10.34	8992.0
108	11664	10.39	9160.9
109	11881	10.44	9331.3
110	12100	10.49	9503.3
111	12321	10.54	9676.9
112	12544	10.58	9852.0
113	12769	10.63	10029
114	12996	10.68	10207
115	13225	10.72	10387
116	13456	10.77	10568
117	13689	10.82	10751
118	13924	10.86	10936
119	14161	10.91	11122
120	14400	10.95	11310
121	14641	11.00	11499
122	14884	11.05	11690
123	15129	11.09	11882
124	15376	11.14	12076
125	15625	11.18	12272
126	15876	11.23	12469
127	16129	11.27	12668
128	16384	11.31	12868
129	16641	11.36	13070
130	16900	11.40	13273
131	17161	11.45	13478
132	17424	11.49	13685
133	17689	11.53	13893
134	17956	11.58	14103
135	18225	11.62	14314
136	18496	11.66	14527
137	18769	11.70	14741
138	19044	11.75	14957
139	19321	11.79	15175
140	19600	11.83	15394
141	19881	11.87	15615

No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
142	20164	11.92	15837
143	20449	11.96	16061
144	20736	12.00	16286
145	21025	12.04	16583
146	21316	12.08	16742
147	21609	12.12	16972
148	21904	12.17	17203
149	22201	12.22	17437
150	22500	12.25	17671
151	22801	12.29	17908
152	23104	12.33	18146
153	23409	12.37	18385
154	23716	12.41	18627
155	24025	12.45	18869
156	24336	12.49	19113
157	24649	12.53	19359
158	24964	12.57	19607
159	25281	12.61	19856
160	25600	12.65	20106
161	25921	12.69	20358
162	26244	12.73	20613
163	26569	12.77	20867
164	26896	12.81	21124
165	27225	12.85	21382
166	27556	12.88	21642
167	27889	12.92	21904
168	28224	12.96	22168
169	28561	13.00	22432
170	28900	13.04	22698
171	29241	13.08	22966
172	29584	13.11	23235
173	29929	13.15	23506
174	30276	13.19	23779
175	30625	13.23	24053
176	30976	13.27	24328
177	31329	13.30	24606
178	31684	13.34	24885
179	32041	13.38	25165
180	32400	13.42	25447
181	32761	13.45	25730
182	33124	13.49	26016
183	33489	13.53	26302
184	33856	13.56	26590
185	34225	13.60	26880
186	34596	13.64	27172
187	34969	13.67	27465
188	35344	13.71	27759
189	35721	13.75	28055
190	36100	13.78	28353
191	36481	13.82	28652
192	36864	13.86	28953
193	37249	13.89	29255
194	37636	13.93	29559
195	38025	13.96	29865
196	38416	14.00	30172
197	38809	14.04	30481
198	39204	14.07	30791
199	39601	14.11	31103
200	40000	14.14	31416
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4. PENDULUM-MATIC LEVEL WIND . . . This spooling unit is not mechanically linked to the winch drive; consequently, it automatically compensates for any change in rope diameter, stretch, speed or wear. Patent No. 2,462,297.
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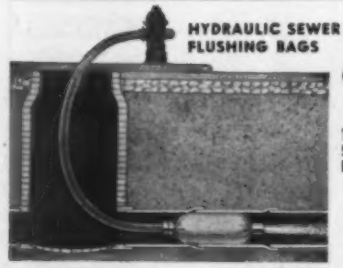

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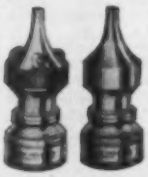

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LLOYD D. KNAPP
Superintendent,
Bureau of Sewers, Milwaukee, Wis.

THE Bureau of Sewers designs, constructs, operates and maintains all combined, sanitary and storm sewers in the City of Milwaukee. All house sewers, from the main sewer to the building, are the property and responsibility of the property owner, and must be cleaned and maintained by him. The Milwaukee Sewerage Commission designs, constructs, operates and maintains intercepting sewers and a sewage treatment plant for the entire metropolitan area. The Commission was organized in 1913. Prior to that time all sewers in the City were of the combined type and emptied directly into one of the three rivers or into Lake Michigan.

Since 1915, the city has constructed separate sanitary and storm sewers in its newly annexed territories. Today the Bureau is responsible for approximately 500 miles of combined sewers, 300 miles of sanitary sewers and 300 miles of storm sewers. These sewers, most of which are circular, range in size from 6 in. to 144 in. diameter. Some of the storm sewers are of a rectangular section, the largest of which is a double box, with each side measuring 7 ft. by 10 ft.

The older sewers were built of clay pipe, natural cement concrete pipe and brick. The natural cement concrete pipe sewers were either 12 in. diameter circular, or egg-shaped 12 in. by 18 in., or 15 in. by 21 in., with a flat base to facilitate laying. Most of the older sewers 24 in. diameter or larger were built of brick, and in few instances of planks. Today vitrified clay pipe is used in sizes up to 36 in. diameter, concrete pipe in sizes up to 66 in. diameter, and monolithic concrete for box sections and circular sections as small as 48 in. diameter. Vitrified clay liner plates are used where needed in the monolithic sewers and in pipe sewers 42 in. diameter and over.

It is present policy to use concrete pipe for sanitary and combined sewers in residential and local business areas, and to use vitrified clay pipe in light manufacturing and industrial districts. Zoning is quite well stabilized, and this policy has proven satisfactory over a long period of years. The sewers are quite well ventilated and, since the establishment of the Sewerage Commission, designs have provided for minimum velocities of 2 ft. per second. There are, therefore, but few septic conditions, and there has been no known trouble with hydrogen sulfide gas in the residential areas.

Organization

The Bureau of Sewers is organized into a construction division, an engineering or design division, an accounting division, and a maintenance diivsion. This latter division is in charge of the cleaning, flushing and repair of all sewers and appurtenances, as well as the construction of all catch basins, storm inlets and overflows. The division is under the direct charge of a field supervisor and an assistant. The city is divided into three districts, each under the supervision of a district foreman reporting to the field supervisor. Each district foreman is in charge of two or three construction gangs, consisting of a foreman with eight or ten men, a catch basin cleaning crew, one or two sewer cleaning gangs, a flushing crew, one or two sewer masons with helpers, a troubleman, and a timekeeper. At division headquarters there is a blacksmith, a carpenter, and a machinist, all with helpers, and two sewer examining crews of three men each.

All city-owned automotive equipment, such as automobiles, trucks, trailers, air compressors, eductors, concrete mixers, cranes, etc., are operated and maintained by the Bureau of Municipal Equipment. This equipment is rented to the various other bureaus as needed and at rates somewhat below that charged by private owners. Special equipment such as pumps, cleaning machines, steamers, etc., are in direct charge of the Bureau of Sewers.

Construction Crews

The construction crews excavate for the catch basins, and construct storm inlets and overflows during the construction seasons. These crews also build short sections of new sewers as the occasion may require.

Catch basin and manhole bottoms are poured with ready-mixed concrete and, where conditions permit, steel forms are set up and the bottom half of the catch basin is also poured with ready-mixed concrete. A sandbag is placed in the form to provide an opening for the overflow pipe and trap. A sewer mason follows this crew and lays up the top half of the catch basin with concrete brick.

The storm inlet assembly consists of a frame and grate with a side inlet box resting on a layer of brick. The brick rests on the edge of a large cast iron bowl, and the bowl in turn rests on a cast iron elbow with a 15-in. radius. The elbow has a large flat base to facilitate placement, and after it has been set and backfilled with gravel, the rest of the assembly is quickly put together. The frames, grates, and side inlet boxes used in storm inlet construction are identical with the castings used for catch basins.

Each crew has a combination tool wagon and shanty equipped with a small stove. Each crew is assigned an air compressor with sufficient capacity to operate two jack hammers continuously. The city owns both trailer-mounted and truck-mounted compressors and an effort is made to keep one truck-mounted compressor in each district for emergency use. The older compressors are mostly Sullivan or Ingersoll Rand, while the newer machines are LeRoi. Each crew also has two jack hammers, two clay diggers, and a demolition tool. This latter tool is a small compact rig that can be used inside a catch basin or manhole for tearing out masonry work. These pneumatic tools are of various makes such as Sullivan, Cleveland, Ingersoll Rand, and Chicago Pneumatic. All of the pneumatic equipment has proven satisfactory.

Each construction crew also has a 1½-in. C. H. & E. centrifugal pump, two wheelbarrows, screw jacks, 200 ft. of 2½-in. flushing hose, 100 ft. of 1-in. flushing hose, a hydrant valve, barricades, red flags, lanterns, and miscellaneous small tools. These special hydrant valves are used to regulate the flow of water, thus permitting the hydrant itself to be open to full capacity. The Water Department recommends this practice as a means of preventing wear and tear on the hydrant parts.

The city owns one truck-mounted Hydro-crane with a ¼-cu. yd. bucket, which the Bureau of Sewers uses on a year-around basis. One or two more of these cranes are rented during the construction season. These cranes are operated hydraulically, even to the opening and closing of the bucket. They are used for digging purposes, and they operate quite successfully where the ground is not too hard.

The advantages of this type of machine are that it can be quickly moved from place to place in an emergency and can be digging 2 or 3 minutes after arrival on the job. The machine is mounted on an International Truck chassis and can travel

Le Roi 105-160 Cu. Ft. Per Min. Two Stage Compressor Mounted on International Truck.

*Reprinted from Sew. Wks. Jour., Vol. 21, p. 475 by permission.

Sewer Cleaning Machine With Self-Closing Bucket Manufactured by Turbine Sewer Machine. Co.

along city streets safely at a speed of 25 to 30 miles per hour. This equipment is used to greatest advantage in the outskirts where there is little interference from other underground structures. One 2½-cu. yd. dump truck accompanies each Hydro-crane. This is sufficient, especially in the outskirts where a dump can usually be found within a 5- or 10-minute run. These cranes are also used in the older sections of the city, at locations where digging conditions are favorable. Experience with the Hydro-cranes to date indicates that under favorable conditions the cost of excavation can be reduced approximately 30 per cent over hand digging.

Otherwise all digging for catch basin and overflow construction as well as for sewer repairs is done by hand. The hand digging crews load their dirt into trailers of about 5 cu. yd. capacity. The empties are spotted and loads pulled once a day.

In the winter months the construction crews are put out on repair jobs. They remove and replace broken or cracked pipe, break out and replace defective concrete in tunnels, and break out defective masonry in the brick sewers preparatory to repairs to be made by the sewer masons. One extensive repair job carried over several winter seasons, involving the removal and replacement of concrete in the lower quadrant of a 72-in. tunnel and the lining of same with vitrified clay liner plates. This was a storm sewer tunnel into which acid had been discharged for several years. Winter digging is admittedly expensive, but it has been necessary to operate all winter in order to keep the crews manned with experienced men, and because it is not possible to hire sufficient men to make the necessary repairs in the summer months when the construction program is heavy. Then too, it would be difficult to secure the extra tools and equipment needed to do both repairs and construction in the summer.

The city of Milwaukee for years has had an Accident Prevention Committee composed of key representatives of the various operating departments. The field supervisor is the representative for the Bureau. This committee has done much to promote safety among city employees. Supervisory forces make it a point to instruct new men in the use of tools, to examine tools for defects, etc. Supervisors are especially particular in the bracing and shoring of trenches and tunnel sections. Men are not permitted to work in the so-called "rat hole" sections. As a result of these precautions the usual accidents are of a minor nature. There have been no accidents due to cave-ins for many years.

Sewer Cleaning

There are four sewer cleaning crews of three men each. One crew is using a pair of Champion 7.5-h.p. machines; while two crews are using a pair of Sewer Turbine 7.5-h.p. machines. One crew has a pair of 3-h.p. Sewer Turbine machines. The smaller machines are used on the smaller sewers so as not to overload the motors. All of the machines are proving satisfactory. However, the level winding apparatus was removed from the Champion machines and substituted by a loose pulley. The gearing on the Turbine machines was also changed so as to increase the cable speed from 33 to 90 ft. per minute. Self-closing buckets are used in sizes from 6 in. to 18 in., made by the Champion Company. Some plain buckets or scoops have been made up to fit several different sizes of small egg-shaped sewers, and circular scoops have been made for sewers 21 in. diameter or larger.

Elm strips ½ in. by 2 in. and of varying lengths up to 10 or 12 ft. are used in getting the pilot cables through the sewer. These strips are notched at the ends and fastened together with wire. They are quite flexible and can be readily shoved through the sewer. Any water in the sewer, of course, will cause the strips to float and facilitates their use. If the normal flow in the sewer is not sufficient to float the strips it is an easy matter to connect a hose to the nearest hydrant and obtain the amount of water desired. Jointed, wooden sewer rods about 1½ in. square and in 3-ft. lengths are used for the same purpose. When neither the elm strips or rods will work, a Flexible sewer rod is put through and the pilot cable pulled back when the rod is withdrawn.

Sewers under busy streets or car tracks are cleaned at night. When cleaning along car tracks, hand cleaning rigs are employed, as these can be shoved aside more readily than the power machines in order to let street cars pass.

Flushing

Four flushing crews of three men each are maintained. Each crew is equipped with about 500 ft. of 2½-in. hose, one 8-in. and one 12-in. flushing bag, a wheelbarrow, manhole guards and various small tools. During the winter a stiff rubber coated hose is used, from which the water can be drained and which will not freeze up during severe cold. In the warmer months discarded fire hose is employed, which is bought from the Fire Department for 10 cents a foot. One length of the rubber covered hose is shoved down the manhole and into the sewer because of ease of handling. Hose bridges are made by a carpenter and consist of cham-

Elgin Eductor Mounted on Sterling Chassis—Note Agitator Pipe and Long Handled Rake for Cleaning Out Sticks.

fered 3-in. planks fastened together with steel bands. Discarded rubber hose is cut up and nailed on the bottom of the planks and this prevents skidding of the hose bridge under impact of even heavy vehicles, provided they travel at moderate speed. During 1947, 262 miles of sewers were flushed.

All storm inlets are flushed once a year by these same crews. There is a considerable waste of time in coupling up hose to the nearest hydrant, setting the hose bridges, etc., only to find that one good shot of water is all that is needed. The field supervisor is now studying the possibilities of using power flushers for this work.

Catch Basin Cleaning

Catch basins are cleaned once a year. This work is carried out by two catch basin cleaning crews, each consisting of a foreman and eight to ten men. Each crew has three or four Elgin eductors, a 1½-ton truck, a wheelbarrow, a small centrifugal pump and various miscellaneous tools. Each educator crew will clean an average of twenty catch basins per day. The truck and two men are used to clean, by hand, those basins which are inaccessible to the eductors, and to finish cleaning those basins which cannot be properly cleaned by the eductors. Each eductor crew carries a garden rake for removing sticks, branches, etc. They frequently find chunks of broken concrete or other material which cannot be removed either by the eductor or by the rake, and the extra cleaning is then taken care of by this manual cleaning gang. The eductors are over 20 years old and are in need of replacement. It is hoped soon to inaugurate a program of modern equipment replacements.

The eductors operate about 8 months of the year, which is about all that weather conditions will permit. During the winter months the crews do hand cleaning of catch basins.

Last year 19,262 catch basins were cleaned by eductor and 5,099 by hand. Admittedly hand cleaning is more expensive, but there will always be many catch basins that cannot be cleaned with the present equipment. And, invariably, either weather conditions or appropriations for equipment rental will interfere before the complete rounds can be made of all catch basin cleaning work. There are approximately 25,000 catch basins and 15,000 storm inlets. The inlets are taken care of, as previously mentioned, by the flushing crews.

Bucyrus-Erie H-2 Hydrocrane Mounted on International Truck Chassis with Orange Peel Bucket for Cleaning Catch Basins.—(This practice is new since the article was written.)

The foreman is furnished with blue line prints of quarter-sections showing the location of all catch basins and storm inlets. He returns these maps to headquarters showing the date of cleaning and notes as to the structural condition of the basins.

Sewer Troublemen

Each district has a sewer troubleman who drives a pick-up truck. His duty is to investigate all complaints in his district. These complaints cover a wide range of subjects, from water standing in the gutter to a leaking kitchen faucet; from rats crawling out of plumbing fixtures to rubber balls lodged in downspouts. In most cases the Bureau of Sewers is not involved, but the troubleman will give the best advice of which he is capable.

The troubleman opens up blocked sewers and catch basins, calling on the nearest labor gang for help. A troubleman and two laborers are on duty every Saturday, Sunday and holiday to handle emergency calls and one of the troublemen is always subject to call by the City Hall night complaint clerk.

During storms, when hundreds of complaints may come in, various foremen and some of the better class laborers are used on trouble shooting service. At such times the maximum number of crews are operated that can be provided with transportation. These forces stay on the job until every complaint has been investigated. In some instances this has taken as many as 36 hours of continuous operation.

Troublemen are also employed during slack periods with the delivery of small orders of materials for construction crews and the moving of the flushing crews and brickmasons from job to job. They also answers complaints on loose manhole covers. If the cover and frame are found to be in reasonably good condition the cover is sealed in place with Hallemite, which has been giving us good service. All flushing crews carry a small supply of this compound.

Hough End Loader Used for Cleaning Up Jobs and Loading Hand Excavated Material. (This practice is new since the article was written.)

Cleaver-Brooks Oil Burning Steamer for Thawing Out Frozen Catch Basins, Storm Inlets and Culverts.

Sewer Inspection Crews

There are two sewer examining crews consisting of a foreman and two men each. These crews have trained personnel and special equipment, and have regular programs for examining sewers as to structural conditions, amount of flow, depth of deposit, etc. Many sewers are flushed or cleaned in accordance with the information obtained from these reports. When a street is to be repaved, an examining crew inspects the sewers, and the designers use their report to determine the necessity of rebuilding the sewer because of its structural condition.

These crews are used for many types of work. They examine all contract work, upon completion, and discover many defects overlooked by the inspector, or which could not be determined by the inspector working alone. They are used frequently in tracing out the point at which given house services and overflows are connected to the sewer. They check for highwater marks in manholes following storms, and occasionally they make house to house surveys to determine the extent of backwater conditions.

These crews are so valuable that their services are in constant demand by the construction forces, engineering division and also by district foremen. It is difficult to keep them at their primary task of examining sewers on a routine basis.

Examinations of the smaller sewers are made by means of flashlights and mirrors. The men crawl or walk through all sewers 30 in. in diameter or larger, flow conditions permitting, and occasionally crawl through 24-in. sewers.

Each crew has a safety belt for use in deep manholes, rubber coats, hats and boots for ordinary work and rubber suits for very wet, dirty work. They also carry a Wolff safety lamp, aluminum ladders for use where manhole steps are unsafe or missing, a small quantity of potassium permanganate, and a considerable number of small tools and supplies.

Sewer Masons

There are four sewer masons, each with two helpers, who work the year around. During the construction season, when the new catch basin work required in connection with new paving is the heaviest, two or three more mason crews are added to build basins and to set basins and manhole frames to final grade. Because of past budget restrictions it has been necessary to impose on some of the more skilled laborers to do this work without extra pay. This past summer, however, it was possible to obtain for three of the best men the regular sewer mason pay for a period of a few months. A plan is now in development to pay four of the best men a rate $15 per month above that of common labor. These men will be used normally as leading helpers to a sewer mason. In the rush seasons they will be used for setting manholes and catch basins to grade, thus relieving the regular masons for the more skilled work of building manholes and catch basins.

There are more brick repairs than can be handled with the four regular masons during the off season. There are perhaps 25,000 catch basins and approximately 40,000 manholes, most of which are built of brick and many of which need repairs, as well as many, many miles of brick sewers which need more and more repair work as they become older.

At the present time the mason crews have only a small tool box, but a program is planned to equip all crews with a small combination tool wagon and shanty.

Yards

At the district yards there is a supply of special tools and equipment as needed, such as centrifugal pumps up to 4-in. discharge, 4-in. Pemberthy syphon pumps, three Homelite blowers operated by gas engines, two electrically operated blowers, three 1500-watt portable light plants, and a Cleaver Brooks oil-burning steamer for thawing out frozen catch basins. There are small derricks and two hoists operated by compressed air and two operated by gas engines, also flumes of various sizes, rock drills, and cutting and welding equipment. In addition there are three Flexible sewer rod outfits which are used in opening up blocked sewers and Coleman rods for use in checking clogged house sewers.

The clerical forces keep time and material records, order materials and equipment, keep a card index file of complaints by house numbers, type the reports of the examining crews, tabulate the records of cleaning, flushing, etc. Ready-mix concrete, backfill gravel, brick and pipe are purchased on open order and may be secured as needed from the vendor, who delivers directly to the job.

In all there are 160 people in the operation and repair division, which includes all classes from laborers and clerks on up to the field supervisor. Common laborers are known as "city laborers" and do sewer cleaning and flushing and catch basin cleaning. They receive a top pay of $140 per month, plus a cost of living bonus of $83.02 per month. The laborers on construction crews are called "sewer laborers" and receive a top pay of $150 per month, plus the cost of living bonus. Sewer examiners get $165 per month, their foreman and the troublemen get $180 per month, while the construction crew foremen receive $210 per month, all with the cost of living bonus in addition. The highest, of course, is received by the field supervisor, who gets $350 per month and the bonus. The total budget for operation and repairs for 1948 amounted to $529,459, approximately $480 per mile.

Typical Flushing Crew—Note Regulating Valve Which Permits Hydrant to be Open to Full Capacity.

Fairbanks-Morse 4-in. Centrifugal Woods Trash Pump with 20 hp. Le Roi Motor.—(Capacity 70,000 gph. Used for pumping out sewers, basements, flooded areas, etc.)

Discussion

Francis S. Friel
President,
Albright and Friel, Inc., Con. Engrs.,
Philadelphia, Pa.

Mr. Knapp has given an excellent outline of the scope of the organization, equipment and maintenance procedures of the Milwaukee Bureau of Sewers.

In Mr. Knapp's remarks relating to sewer construction he reports that all house sewers from the main sewer to the building are the responsibility of the property owner and must be cleaned and maintained by him. This same practice prevails in the Philadephia area. Prior to the war, one suburban area outside of Philadelphia made house connections through contract, within the bed of the street, and charged the property owners a fixed sum for it. This practice has been stopped because of present labor conditions, and now property owners are required to engage their own contractors who, in turn, must be bonded by the municipality.

Reference is made to the practice in Milwaukee of using vitrified clay pipe for sewer lines up to 36 in. in diameter; concrete pipe up to 66 in. in diameter and monolithic concrete structures with vitrified clay liner plates where needed. It is also interesting to observe that it is the policy in Milwaukee to use concrete pipe for sanitary and combined sewers in residential and local business areas, and to use vitrified clay pipe in light manufacturing and industrial districts. This practice is commended.

Mr. Knapp does not mention any difficulty experienced in locating manholes or other sewer structures. Manholes are often covered with new paving or by grading of private property or regrading of roads, and instruments to locate them are invaluable in time-saving. Magnetic dip needles are convenient for shallow depths, while the "M-scope" is required for deeper coverage.

The use of the sewer examining crews for inspection of new construction and for periodic examination of lines is good practice. The best insurance against excessive maintenance is a well-designed and well-constructed sewer line. A small municipality in Pennsylvania installed a sewer system about 25 years ago. The sewers were poorly constructed due to a lack of proper inspection. Since the original construction, more than twice the first cost has been spent by the town and by W.P.A. in attempting to repair the sewer lines. In some instances, a pipe between two manholes, located less than 300 ft. apart was out of alignment as much as 3 feet. In addition, the system leaked badly. The unsatisfactory conditions in this sanitary sewer system have not been corrected and a large expenditure is still necessary to complete the rectification of the original unsatisfactory work. Money spent for good engineering and inspection pays dividends on future maintenance.

The disintegration of sewers, as indicated by the need for a retreading job on a 72-in. sewer noted in Mr. Knapp's paper, once again illustrates the need and justification for regulation of the disposal of industrial wastes, taking into account the character as well as the volume of the wastes to be handled. In some cities, surveys have been made to eliminate the discharge of industrial wastes, particularly strong acids, which might cause the disintegration of sewer lines. It is certainly logical to require a particular industry to neutralize strong wastes prior to their discharge to a sewer system.

The frequency of cleaning of a sewer line is dictated by the character of sewage, the flatness of the sewer grades, the condition of the pipes themselves and also possibly by weather and climatic conditions. No hard and fast rule can be applied as to the interval between the cleaning of a sewer. In Lower Merion Township, Pa., the sewers are flushed once a year. The conditions observed during the flushing period form the basis of a priority maintenance program. All free time of the maintenance crew is used in a systematic cleaning of the 142 miles of sewers. Six years are required for the complete coverage cycle. A force of four men with one truck and up-to-date cleaning equipment does the job. The superintendent reported recently that only three stoppage complaints have been received in five years.

There are some instances where sewers have never been cleaned since they were installed. On the other hand, certain sewers have clogged in a relatively short period of time due to the growth of tree roots and other external causes.

The use of a flexible steel type of sewer rod to clean sewers has proved advantageous in many places throughout the country. This type of equipment may be used to remove obstructions which cannot be dislodged by a wooden rod. It is especially effective where fire plugs may not be available and when extra flushing

Bucyrus-Erie H-3 Hydrocrane Mounted on International Truck Chassis—Clam Shell Bucket for Excavating Work.

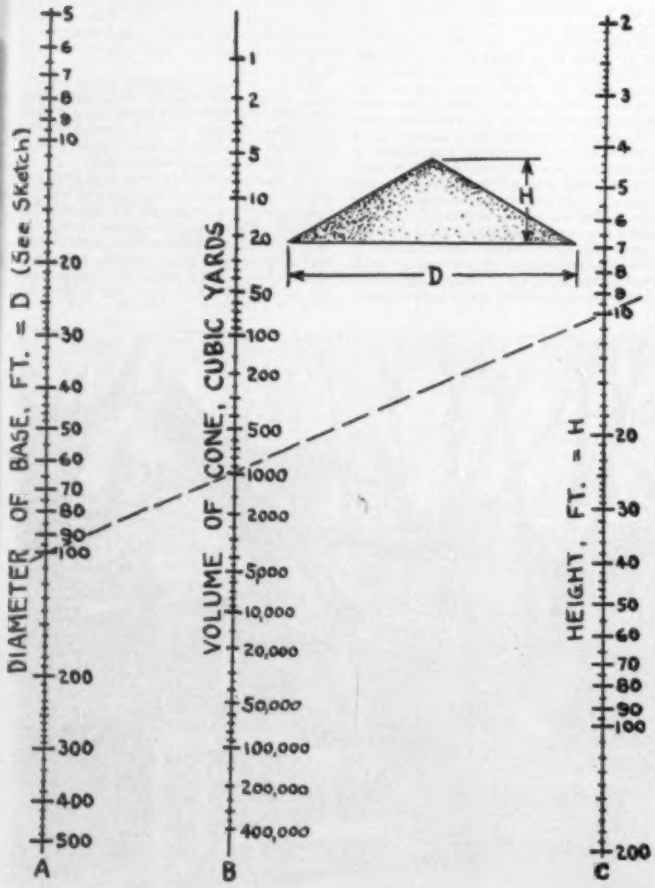
water must be hauled to the work. There also is a safety factor involved in using flexible steel rods, since the men are working above ground.

The mechanical cleaning at Milwaukee is apparently by the drag-line type of cleaner. This type of apparatus is effective but is inclined to cut tracks in deposits where flows are small. The water-driven turbine type will do its work well, but the writer does not believe that this latter type of equipment is equal to the revolving spring-steel rod utilizing different kinds of cleaning or cutting heads, and the rubber cups for removing sand or other deposits when backed by a head of sewage.

Flexible sewer rods and machines were found to be valuable cleaners at Boston (*American City*, August, 1942). At Los Angeles, Brown states that nearly one and one-half million feet of sewer lines are cleaned each year with three machines, and the cost of upkeep and personnel was 3½ cents per foot of sewer pipe cleaned. Mr. Brown states that each machine may be set up at 10 to 20 locations a day and can clean from 1500 to 2500 ft. of sewer line daily (*Water and Sewage Works*, p. 249, 1947).

Catch basins at Milwaukee are cleaned once each year. This practice varies throughout the country. In some places they are cleaned as often as once every 3 months, while in other instances the period of cleaning is extended to about once in 3 years, as in Boston. The eductor type of catch basin cleaning apparatus as mentioned for Milwaukee is most effective, and reduces the unit cost for the removal of grit and other foreign material.

In most municipalities, where the water works is owned by the city, there is no problem in securing water for flushing sewers, but where a private company owns the water works, the problem differs materially. Again citing the case of Lower Merion Township, it is cheaper to use creek water for flushing than to purchase water from the private utility. The township, which has an area of 24 sq. mi., has a 700-gal. tank mounted upon a 2½-ton truck, and water is pumped to this tank from a series of creeks or taken from one of the twelve fire hydrants permitted to be used. The tank is equipped with a quick-opening valve, and the contents are discharged rapidly to a manhole for flushing.



CONTENTS OF CONICAL PILES*

Frequently it becomes desirable or necessary to estimate yardage in a pile of dirt, sand, stone, gravel, coal, etc.

Without any figuring whatever the accompanying chart quickly gives the number of cubic yards in any conical pile.

For example, how many cubic yards in a conical pile whose based diameter is 100 ft. and whose height is 10 ft.?

The dotted line drawn across the chart shows how it is done. Run the line through the 100 ft. diameter, column A, and the 10 ft. height, Column C, and the intersection with column B gives the answer as a little less than 1000 cubic yards.

The range of the chart takes care of all diameters from 5 to 500 ft. and all heights from 2 to 200 ft. However, in the event that diameters or heights should be greater or less the same chart is still applicable. Thus if the diameter should be 1000 ft. instead of 100 ft. and if the height should be 100 ft. instead of 10 ft., the same dotted line would solve the problem excepting that the answer would be 1,000,000 cubic yards instead of 1000 cubic yards. In that case the rule is this: For every cipher added to column A, add two ciphers to the answer in column B, and for every cipher added to column C, add one cipher to the answer in column B. This means that when the problem is 1000 ft. diameter and 100 ft. height, three ciphers must be added to the result in column B.

*Contributed by W. F. Schaphorst, M.E.

OIL WASTE EXCLUSION FROM SEWERS

Baltimore Experiences with a Workable Ordinance

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IN 1927 a fire near the outlet of the largest storm drain in Baltimore resulted from the escape of gasoline and oil into the drain. Causing no serious damage, it did, however, result in passage of a city ordinance requiring daily storage of waste oil, crankcase drainings and greases in approved steel drums by all users of such materials.

The Baltimore Ordinance No. 1083

An ordinance to regulate the handling, storage, transportation and disposition of waste oils and greases resulting from the use, operation, cleaning, repairing or servicing of vehicles, machinery or appliances of any kind upon all premises in Baltimore City; providing for enforcement, and also providing a penalty for violation of the provisions of this ordinance.

Section 1. Be it ordained by the Mayor and City Council of Baltimore, That from and after the date hereinafter provided, the following rules and regulations shall apply to the handling, storage, transportation and disposition in the City of Baltimore of waste oils and greases resulting from the use, operation, cleaning, repairing or servicing of vehicles, machinery or appliances of any kind:

(a) All waste oils, including crank case drainings, shall be immediately taken up and deposited and kept while on the premises in steel drums, the character, size construction, number and location of which shall be from time to time prescribed by the Board of Fire Commissioners of Baltimore City, or in containers of other construction approved by the Chief Engineer of Baltimore and by the said Board.

(b) All waste greases shall be collected at least once daily and deposited and kept as in the manner provided for waste oils in the preceding paragraph, and in no case shall any waste greases be permitted to remain in or about any premises over night, except when so deposited.

(c) All such drums, containers and their appurtenances shall be kept and maintained at all times in first class condition and tightly closed so as to prevent the escape of any of the contents thereof, and shall be used for no purpose other than the storage and transportation of waste oils and greases.

(d) The Mayor and City Council, acting through the Chief Engineer of Baltimore, shall determine from time to time the agencies by or through which all such drums, containers and/or the contents thereof shall be removed, stored, transported and disposed of, and the times when, the places where and the manner in which the same shall be done, and such determination shall be subject to the approval of the Board of Fire Commissioners of Baltimore City; and no such drums, containers and/or contents shall be removed, stored, transported or disposed of in any other manner or through any other agency.

Section 2. And be it further ordained, That this ordinance shall not be construed to prohibit the sale and/or reclamation of waste oils and greases, provided, on such sale and/or reclamation, said waste materials are otherwise handled, stored, transported and disposed of in accordance with the terms and provisions of this ordinance and any rules and regulations made in pursuance thereof.

Section 3. And be it further ordained, That terms used in this ordinance are hereby defined as follows:

The term "waste oils and greases" shall include all oils and greases which, by reason of previous use in and about vehicles, machinery or appliances of any kind, are in such condition as to be unfit for further use for such purposes without reclamation.

The term "premises" shall include all real and leasehold property where such vehicles, machinery, or appliances of any kind are used, operated, cleaned, repaired or serviced.

The term "person" shall include persons, firms and corporations.

Section 4. And be it further ordained, That any person violating any of the provisions of this ordinance shall be subject to a fine of Fifty Dollars ($50.00) for each and every offense.

Section 5. And be it further ordained, That the Board of Fire Commissioners of Baltimore City are hereby charged with the duty of enforcing the terms of this ordinance.

Section 6. And be it further ordained, That all ordinances, or parts of ordinances, inconsistent with the provisions of this ordinance be, and the same are hereby repealed to the extent of such inconsistency.

Section 7. And be it further ordained, That in the event that any word, phrase, clause, sentence or section of this ordinance shall be declared invalid by any court, the remainder of the ordinance shall not be affected thereby, but shall remain in full force and effect.

Section 8. And be it further ordained, That this ordinance shall take effect three (3) months after the date of its passage and approval.

Approved May 11th, 1927.

HOWARD W. JACKSON, Mayor.

Attest: A True Copy:
JOHN A. SLOWIK, City Librarian.

Collection Contracts

In order to provide for the collection of these materials the city entered into a two-year contract with a collection company. Since the first contract expired, Sept. 30, 1929, the work has been done by three companies at different times. The cost to the city is shown in the accompanying table.

During this sixteen-year period 4,287,714 gallons of oil and greases have been collected. This is equivalent to 263,860 gallons yearly at an average cost of 7.5 mills per gallon.

Cost of Collecting Grease and Oil in Baltimore from 1927 to 1943

Year	Contractor	Amount paid contractor	Grease and oil collected, gal.
1927	Provident Oil Service Co.	$ 810	71,701
1928		3,240.00	265,000
1929		3,037.50	318,000
1930		2,430.00	286,850
1931		2,430.00	280,100
1932	Thomas Leonard	2,422.50	229,299
1933		2,490.00	139,804
1934		2,400.00	143,280
1935		2,360.00	155,690
1936		2,000.00	169,515
1937		2,000.00	156,150
1938		1,625.00	120,940
1939	City Waste Oil Co.	500.00	327,440
1940		500.00	437,420
1941		768.75	473,420
1942		1,575.00	416,099
1943		1,575.00	297,006
	Total	$32,013.75	4,287,714

The contractor is required to furnish steel drums for the storage and transportation of oil and greases where the amount collected is more than 20 gallons weekly. For lesser quantities, the containers are furnished by those who must dispose of the oil or grease. Containers must be collected within 24 hours after they are full.

The present contractor has three 1,000-gal. tank trucks for the transportation of the materials. Each truck is equipped with a suction and a discharge pump for handling the oils.

Oil Purification Plant

Oil is discharged from the tank truck into an underground storage tank, from which it is pumped into a 2,000-gal. dehydrating tank containing steam coils. Moisture evaporation is accomplished by passing steam at 90 lb. pressure through the coils for a period of five to eight hours.

Dehydration is followed by sulfuric acid treatment in a 1,500-gal. storage tank. Sludge precipitated from the oil is disposed of in a lagoon. Clay is added to the partially purified oil which is then cooked with steam at about 600 deg. F. for eight to ten hours. During the cooking the higher volatile hydrocarbons such as kerosene, naphthalene, and the alcohols are distilled off for use as fuel in the steam generating plant.

The oil residue is cooled to approximately 200 deg. F. and filtered in a Shriver plate press, producing a filtrate equal in quality to new oil and ready for sale. About 12 hours are required to complete the process.

The collection and purifying of oil is not unique with Baltimore as similar plants are in operation in New York City, Philadelphia and elsewhere. The unique feature about the practice is that Baltimore has adopted an ordinance requiring daily collection and disposal of greases and oils and has made the necessary provision for having the work done. Since this ordinance has been in effect the sewers in the city have been remarkably free from inflammable materials.

EQUIPMENT AND TOOLS FOR SEWAGE WORKS*

SETH G. HESS
Director-Chief Engr.
Interstate Sanitation Commission, New York, N. Y.

A WELL designed and well equipped sewage treatment plant should have a complete complement of tools and equipment necessary to its proper operation. Quite often it is impossible to foresee, in the design of a plant, just what tools and equipment will be needed, and yet some attempt should be made to provide as much of the equipment as possible. Likewise, in the operation of a treatment works conditions and situations change, thereby making it necessary to increase the inventory of equipment and tools. In either case a list of tools, equipment, and materials for the operation of a sewage disposal plant will be helpful as a guide either to the designing engineer or the operator. Such a list has been prepared and is presented herewith.

Irrespective of the items appearing on any general list, it is essential that the manufacturer or supplier of various machines and equipment furnish the special tools and spare parts for their equipment and machines.

Obviously, various types of plants require different types of equipment. The number of operators available, their previous trades and experience likewise modify these lists. Some operators are adept in carpentry while others have a flair for working in metals. In either case it would be well to expand on the tools and equipment suggested in the following to meet the particular ability of the operators.

At some plants only the smallest repairs are handled, while in others there are sufficient personnel to permit practically all of the maintenance repair work to be done at the plant. Accordingly the tools will have to be modified to meet these conditions. The proximity of repair services likewise influences the type of tools that must be available.

The following list is indicative of the type of tools and equipment used in some hundred sewage treatment plants within the district of the Interstate Sanitation Commission (N.Y., N.J., Conn.) which extends about fifty miles across and includes New York Harbor and adjacent waters.

Equipment

- Adding Machine
- Alemite or Zerk grease guns for plant equipment
- Barricades
- Blower—Air, portable—gasoline driven
- Brooms—Street, ordinary, industrial type
- Brushes—
  - Flue
  - Paint and Whitewash
  - Scrubbing and long-handled
  - Wire
- Blocks and Tackle for ½-in. and ⅝-in. rope
- Boots—Hip and knee
- Cans—
  - 5 gal. for gasoline, safety type
  - 5 gal. for kerosene, safety type
- Rubbish
- Caulking Gun—for glass house windows
- Chain Hoist—one ton capacity
- Concrete Mixer—Portable, gasoline powered
- Dippers
- Electric Drop Light — explosion proof, with extension cord—200 ft.
- Electric Generator — portable, gasoline driven
- Electric Torch Light—1½ or 3 volts
- First Aid Cabinet
- First Aid Emergency Chart (first aid directions)
- Fire Extinguishers
- Fire Pails
- Flags—Danger, for street use
- Flag Tripods
- Flashlights—Hand
- Flood Lights (to operate from portable generator)
- Funnels—Assorted sizes
- Gaskets—Sheet rubber and Vellumoid Gasket Paper
- Gasoline Engine for operating 3/16-in. sewer rods mounted on a two-wheel trailer
- Gloves—Rubber and canvas, work
- Goggles—Safety
- Hydrometers—Battery and Alcohol
- Hose—
  - 2 or 2½-in. for flushing out sewers (with 4x2 or 2½-in. reducer)
  - 300 ft. Garden type
  - Spare Hose for chlorinator
  - 20 ft. suction with strainer and 100 ft. discharge hose for use with power operated pump
- Nozzles—Shut-off type
- Ladders—
  - Extension to 20 ft.
  - Step
- Lanterns—Red, also white globes
- Laboratory equipment as required
- Mop and Handle
- Padlocks
- Paint Sprayer
- Pails—12 qt. heavy galvanized
- Pencil Sharpener
- Picks
- Pumps—2-in.-4-in. portable, self-priming centrifugal, diaphragm or piston, gasoline engine driven
- Rope—½, ⅝ and 1-in. and sash cord or clothesline
- Rubber Raincoats, hats and suits
- Safety Equipment—
  - Explosimeter
  - Gas Mask (chlorine)
  - Harness (safety belt) with 25 ft. ⅝-in. rope spliced on
  - Oxygen breathing apparatus (Chemox)
  - Oxygen deficiency indicator
  - Respirator (for paint spraying, dust, etc.)
- Scum Skimmer
- Sludge Sampling Equipment
- Sludge Shredder
- Sprayer—hand, fly
- Squeegees—Floor and windows
- Torches—Bomb type
- Truck—Light, for carrying equipment
- Two-Wheel Hand Truck
- Typewriter
- Vacuum Cleaner
- Waste Cans
- Wheelbarrow—Rubber-tired
- Wringer Buckets

Garden Implements

- Brush Hooks
- Garden Trowel
- Hedge Clippers
- Hoe
- Hose—
  - Garden type, approximately 300 ft.
  - Nozzles—Shut-off type
- Insect Sprayer
- Lawn Roller
- Mower—
  - Lawn, hand or motor operated
  - Edging
- Pruning Shears
- Rakes—
  - Wood
  - Steel
- Scythe
- Sickle
- Spade
- Sprinklers—Nozzle type

Materials and Supplies

- Alcohol or Anti-freeze
- Assortment of bolts, nuts, washers, screws, cotterpins, rivets, lock washers, cap screws, stud bolts, etc., stored in jars or cans
- Bricks—Common
- Calcium Chloride (for icy pavements)
- Caulking Compound and sewer joint compound
- Caulking Compounds, Durolite or equal, for glass house windows
- Caulking Yarn
- Cement
- Cement—Asbestos
- Chain—Assorted sizes and lengths
- Chamois Skins
- Cleaning Compound, broiler
- Cleaning Powders—assorted
- Cups—Drinking
- Cutter Wheels—spare
- Disinfectants (CN and others)
- Emery Cloth—assorted grades
- Fittings—Brass or Iron—assorted sizes
- Flashlight Batteries
- Fuses—Assorted
- Glass
- Graphite
- Grease—For lubrication
- Hose, Nipples and Clamps for garden hose, extra
- Iron and Boiler Cement
- Kerosene
- Lead and Lead Wool
- Light Bulbs
- Measures—Oil, 1 qt. and 1 pt.
- Mops
- Nails—Assorted sizes
- Oakum
- Oil for lubrication
- Oil—Rust removing, penetrating
- Packing for pumps
- Paint Remover
- Painter's Drop Cloths
- Paints—Turpentine, linseed oil, thinners etc.
- Pipe Joint Compound
- Pipe Stock—depending on system
- Plugs—Rubber Expansion
- Polish—Brass
- Putty
- Rags—Clean and sterilized
- Sand—Stone or gravel
- Sandpaper—Assorted Grades
- Soap
- Solder
- Soldering Paste
- Spare Handles for hammers, hatchets and axes
- Spare parts for all machines and apparatus
- Sponges
- Steel Wool
- Tape—Friction and Electrician's
- Thermometers—Assorted
- Toilet Paper
- Towels
- Valve Grinding Compound
- Waste—Wiping
- Wicks—For torches and lanterns
- Wire—Annealed, No. 10 and No. 16

Tools

- Axes—spare axe handles
- Awls
- Bars—crow
- Bars—wrecking
- Bit brace and assortment of bits for wood and metal
- Blacksmith's anvil, tools, forge and hand blower
- Bolt stock and dies
- Breast drill and assortment of drills
- Calipers—inside and outside
- Calipers—micrometer
- Caulking tools—water main type (assorted sizes and types)
- Chisels—assorted
- Chisels—bull point
- Chisels—cape
- Chisels—cold
- Chisels—diamond point
- Chisels—round nose
- Chisels—assorted—wood
- Chisels—assorted—for air hammer
- "C" Clamps—assorted
- Cotter Pin Puller
- Countersink—assorted for wood or metal
- Cutters—wire
- Cutters—½-in. bolt
- Dies—assorted for bolt and pipe threading stocks
- Drills—assortment
- Drills—electric portable ⅝-in. for twist drills No. 60 to ⅝-in. with drill press stand mount
- Drills—electric portable ¼-in. for twist drills No. 0 to No. 60
- Drills—hand
- Drills—press, bench type

*In the preparation of this list the writer is indebted to Marshall E. Ferguson, Field Technician of the Interstate Sanitation Commission, and to Joseph Doman, Sanitary Engineer, Department of Public Works, Greenwich, Conn., and Leslie E. West, Chief Engineer of the Elizabeth Valley Joint Meeting, who have reviewed the list and very generously offered their comments. The list was also checked against an inventory of the equipment and tools at the sewage treatment plant of the Belgrave Sewer District of which Herbert O. Johnson is superintendent.

Drills—star drills of various sizes
Extractors—screw, various sizes
Files—assorted sizes
Files—flat
Files—half round
Files—round
Files—taper (triangular)
Files—wood rasp
Fire pot—including metal foot and wrought steel ladle—for use with B and S cast iron pipe
Flanging tools—for use with copper pipe
Flaring tools—for use with copper pipe
Fuse Puller
Gages—set of shim
Gages—test for pressure and vacuum
Glass Cutter
Grinder—electric or hand—bench type
Grinder—wheels, coarse, fine and wire brush
Hacksaw—adjustable frame with extra blades
Hammers—Ball pein—assorted sizes
Hammers—Blacksmith's type
Hammers—Caulking
Hammers—Claw
Hammers—Mason's
Hammers—Rubber Mallet
Hammers—Sledge type—various sizes
Hatchet
Jacks—screw or hydraulic—various sizes
Joint Runner—asbestos, for use with lead joints
Lathe—metal, 12-in. swing, 24-in. centers
Lathe tools and appurtenances
Lead Pot and Ladles
Levels—Line
Levels—Spirit—metal frame, 18-in.
Line—Mason
Manhole cover lifting hooks
Mattock
Nail Sets—various sizes
Oil Cans—several types and sizes as required
Packing Hooks
Packing Tools—assorted
Pipe Cutter
Pipe Cutter—wheels (spare)
Pipe Taps
Pipe Thread Taps (combination), ¼ to 2-in.
Pipe Threading stock with assorted dies
Pipe Tripod
Plane—Smooth, bench, 7-in.
Pliers—assorted sizes
Pliers—Diagonal cutting
Pliers—Gas
Pliers—Combination slip joint
Pliers—Needlenose
Pliers—Wrench
Plumb Bob
Puller—gear set
Punches—assorted sizes, center, drift
Putty Knives
Reamers—Hand, Taper, Pipe, Expansion
Rules—6-ft. folding.
Saws—Rip, crosscut, compass and keyhole
Saw Set
Saw Vise
Scale Platform
Screwdrivers—various sizes
Screw Pitch Gauge
Scribers
Sewer Rods and attachments, 3/16-in. and 5/16-in.—3-ft. lengths for house and main line connections
Sharpening Stone
Shears—Tinsmith's, straight and curved blades—assorted sizes
Shovels—Square Point, long and short handle
Shovels—Round Point, long and short handle
Snake—25-ft. spiral
Soldering Iron and appurtenances
Square—steel, large and small
Stamping Tools—steel, letters and numerals.
Straight Edge—Steel
Tampers
Tape—50-ft. steel
Tar Pot
Torch—Blow and gasoline
Trowels—floats, steel and cork assorted
Trowels—pointing
Valve Resetting Tool
Vises—bench and pipe, portable chain vise and stand
Voltage Tester
Wall Scrapers
Washer or gasket cutter for making own washers
Welding outfit with appurtenances, goggles and gloves
Wire Stripper
Wrenches—Adjustable—various sizes
Wrenches—Allen set screw
Wrenches—Box wrench set
Wrenches—Hydrant
Wrenches—Monkey
Wrenches—Open end—various sizes
Wrenches—Ratchet—socket set
Wrenches—Socket—set of various sizes
Wrenches—Spanner
Wrenches—Stillson—various sizes
Wrenches—Torque
Wrenches—Valve

SEWABAZOOKA FOR HOUSE CONNECTIONS

J. R. JACOBS
Superintenedent
Public Works Dept., Moultrie, Ga.

STREET ditching operations frequently go below the level of existing sewers, crossing the house connections for at least one side of the street and necessitating some provision for continuation of service during the period the house sewers are broken or displaced. The problem of maintaining sewer service under these circumstances is readily solved by use of a shop-made gadget dubbed the "sewabazooka." More importantly, the apparatus keeps sewage out of the open ditch, thus avoiding contamination of the work in progress and eliminating odor complaints and unsightly conditions.

Essentially, the unit consists of two sheet metal tubes (Fig. 1) that telescope, as shown in Fig 2, to allow for adjustment to varying conditions. Lengths and sizes for a 4-in. house sewer installation are as shown in Figure 2. All materials are 24-gauge galvanized iron, the longitudinal joints being of the crimped downspout type. The joint between the reducer end and the outer sleeve is soldered.

To use the "sewabazooka," it is telescoped and the inner sleeve is slipped over the sewer coming from the house. By extending the unit as required, the reducing end is slipped into the pipe leading to the main sewer. For ordinary grades and flows leakage is prevented by the overlap of the slip joints. If, however, excessive flows or flat grades require tighter joints, packing with a little oakum or caulking compound generally will suffice.

The total cost of materials and labor for fabricating the unit illustrated, which is for a 4-in. house sewer, was $3.50.

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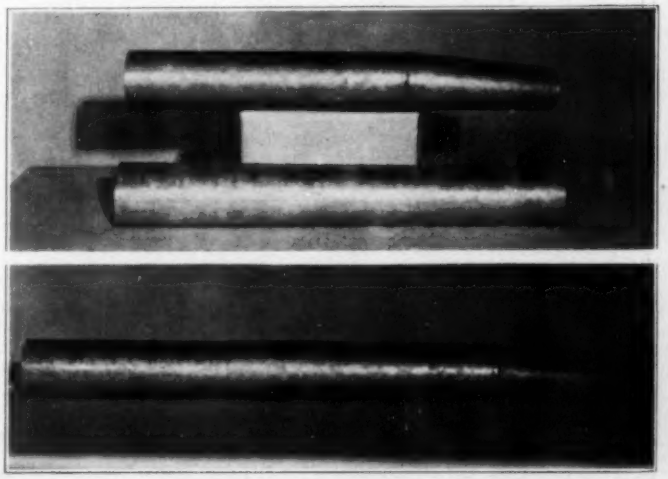

Fig. 1—Telescoping sheet metal sleeves are easily fabricated.

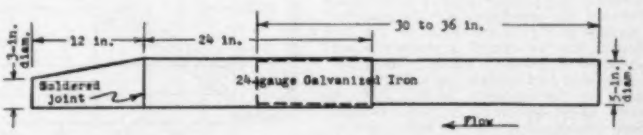

Fig. 2—Details of "sewabazooka" for 4-in. house connection

THE DUAL-FUEL ENGINE AND ITS APPLICATION TO SEWAGE TREATMENT PLANTS*

W. R. CROOKS
Resident Engineer
The Cooper-Bessemer Corporation, Grove City, Pa.

THE dual-fuel engine is an extremely valuable source of power for sewage treatment plants, not only because of its use of a by-product of plant operation, but also because of its versatility of application and economy of operation. Its obvious advantages are such that development has been extremely rapid—so rapid, in fact, that the commercial aspect often has been forgotten and the work pursued like a hobby.

Experimental work with the dual-fuel engine has lead to the most efficient engine known, with a thermal efficiency of 40 per cent at full load. It has lead, also, to an extremely economical source of power having an extremely low maintenance cost. One dual-fuel engine completed 26,400 hr. of operation in the spring of 1949. This engine was operated at overload for a considerable part of the time, so that the load factor for the elapsed time it was in operation is more than 100 per cent. During the first overhaul, a new set of piston rings was all that was necessary to start this engine on its second lap of producing power. It was not even necessary to grind the valves.

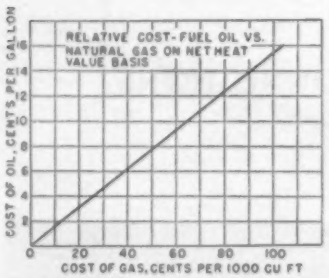

Fig. 1—Relative Cost of Fuel Oil vs. Natural Gas

This paper describes briefly what the dual-fuel engine is, the need for this engine, its development and present status, and its advantages in a sewage treatment plant.

Meaning of Dual-Fuel

The dual-fuel engine has been officially defined by the Diesel Engine Manufacturers Association as "One which uses all oil fuel on the diesel cycle, or predominantly gaseous fuel with oil fuel ignition, and is fully convertible from one fuel to the other." Term "gas-diesel" is officially defined as "A dual-fuel engine that is not instantly convertible." The only difference between the gas-diesel and the dual-fuel engines is that some parts of the fuel system may be altered to convert a gas-diesel to a dual-fuel engine. Cooper-Bessemer dual-fuel engines were brought out prior to the definition by D.E.M.A., so were called gas-diesel engines. However, they are dual-fuel engines, being instantly and, if desired, automatically convertible from fuel oil to 95 per cent gas and 5 per cent pilot oil for ignition purposes. The terms gas-diesel and dual-fuel are used synonomously in this paper.

Some preliminary work was done on the dual-fuel engine in 1928. The original design was rather expensive, and performance was not too satisfactory. The conclusion was reached at that time that the market for such an engine was quite limited and that there was little to be gained in developing it commercially. Many users of heavy-duty gas engines were then using waste gas from the oil industry or sewage treatment plants as their source of fuel. Where low cost gas was not available, diesel engines were offered as a source of power.

Diesel fuel oil sold for approximately 4c per gal., which is comparable to gas costing 25c per 1,000 cu. ft. As the price of fuel oil increased and long-distance gas pipelines became more numerous, it became apparent that there was an economic need for the dual-fuel engine. Such an engine permits the use of gas when it is available, yet does not disturb engine operation when gas is not available due to extremely cold weather or failure of the gas supply. With fuel oil selling for 10c to 15c per gal., the savings are obvious (see Fig. 1). Figure 2 shows the yearly saving per 1,000 h.p. of a gas-diesel over a spark-ignited gas engine for various prices of oil and gas. The savings obtainable by using a gas-diesel over an oil diesel engine are shown in Fig. 3.

Basic Principles

The basic principle of the dual-fuel engine is quite simple. Air and gas for combustion are fed into the cylinder ahead of the compression stroke, just as in the conventional gas engine. At the end of the compression stroke the fuel is ignited by injecting a small amount of fuel oil into the cylinder.

Such a combustion cycle was considered impossible from the time of the perfection of the heavy-duty gas engine (about 1910) until the commercial development of the dual-fuel engine in 1945. Because the high compression in the diesel cylinder is hot enough to ignite even heavy fuel oil, it was assumed that a combustible mixture of gas and air would start burning before the completion of the compression stroke. It was logical to assume that pre-ignition would be so severe that such an engine could not be operated. Every manufacturer of gas engines had found that compression greater than 115 to 125 p.s.i. was very sensitive to pre-ignition and it was only possible to reach such compressions after carefully removing the "hot spots" from the cylinder and pistons. Engineers early learned that a mixture of approximately 1 volume of 1,000-B.t.u. gas and 10 volumes of air was a perfect air-gas ratio and gave the maximum power in a gas engine. All experimental work in attempting to increase the compression was done with this perfect mixture until the dual-fuel development. As soon as the mixture was changed to 1 part of gas to 15 to 30 parts of air by volume, it was found that the combustible mixture of air and gas could be compressed to at least 550 p.s.i. without a trace of pre-ignition or combustion knock. The basic principle of the dual-fuel engine is as simple as that. There were numerous details to be worked out, however, before the basic principle could be made commercially available. The old adage "Trifles make for perfection, but perfection is no trifle" applies here.

Figure 4 shows the comparative heat consumptions of various types of 4-cycle engines and indicates graphically the reduction in fuel consumption by the dual-fuel engine.

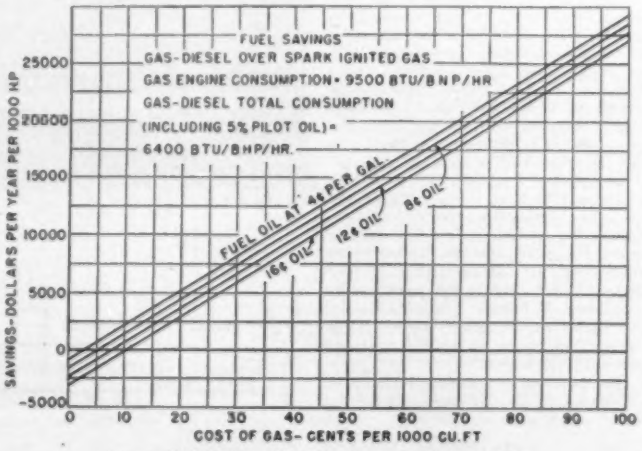

Fig. 2—Fuel Savings—Gas-Diesel over Spark Ignited Gas.

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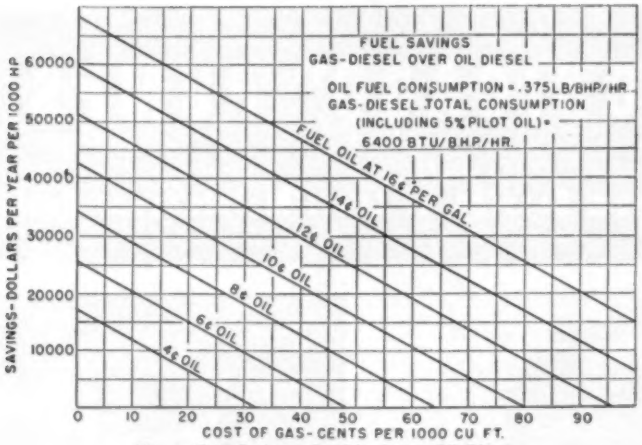

Fig. 3—Fuel Savings—Gas-Diesel over Oil Diesel

Many dual-fuel engines are operating in practically every type of stationary service in sizes ranging from 125 h.p. to 3,400 h.p. Dual-fuel engines have been perfected to the point where, by comparison with the conventional high-grade spark engine, they require 30 per cent less fuel at full load and 50 per cent less fuel at quarter load to produce 1 h.p.-hr. By supercharging, the output of any given engine has been increased as much as 75 per cent. This increased power from a given foundation and engine size appreciably reduces the building and installation costs.

Cooper-Bessemer gas engines have been in successful operation in sewage treatment plants since 1933. They have made a good record, but from a knowledge of disposal plant operations it is believed that the dual-fuel engine is even better fitted for this service because:

1. It provides a source of power as a diesel engine to put the sewage disposal plant into operation, thus freeing the plant from standby charges for electrical power.

2. It eliminates the need for separate heating equipment both for the building and for starting the digestion process, as the waste heat boiler and jacket water provide the necessary heat. This combination provides an over-all thermal efficiency of 65 per cent.

3. It is a source of a definite amount of dependable power at all times. If the sewage gas supply is not enough to meet the power demand, other gaseous fuel (such as natural gas) or fuel oil will automatically make up the additional fuel requirements.

4. It will give long life due to extremely thorough combustion and relatively low operative temperatures.

Recent developments, such as running the gas through purifiers, effective protection of the parts against the corrosive action of sewage gas, use of chrome plated top ring, and basic-type lubricating oils, promise to reduce cylinder and valve wear to that obtainable with the use of the highest grade of fuels.

With the higher cost of fuel and the greater amount of power obtainable from each cubic foot of sewage gas, it is definitely indicated that more and more dual-fuel engines will be used in sewage treatment plants.

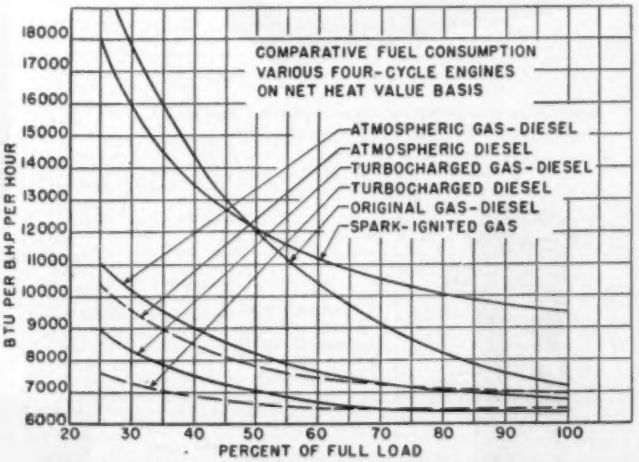

Fig. 4—Comparative Fuel Consumption for Various Four Cycle Engines

Some Relationships Between Current Flow and Heat Production

One Kilowatt
= 56.92 B.T.U. per min.
= 1.34 horse-power.

One B.T.U. per Min.
= 0.01757 KW.
= 0.02356 H.P.

One Horse Power
= 42.44 B.T.U. per min.
= 0.7457 KW.

One Horse Power/Hour
= 2,547 B.T.U.
= 0.7457 KW.H.

One Kilowatt/Hour
= 3.415 B.T.U.
= 80.46 H.P.

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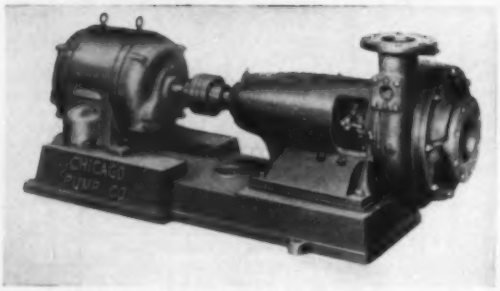

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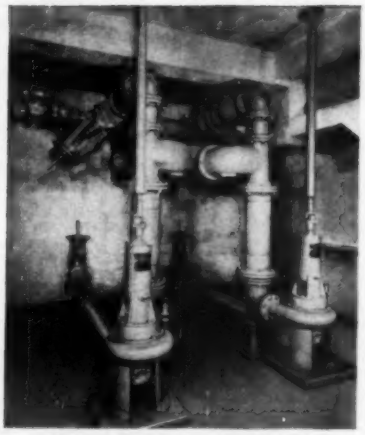

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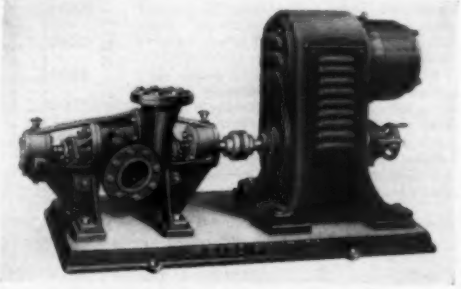

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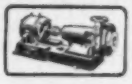

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SEWAGE QUALITY AND CONDITION

Effects on Plant Operation and Efficiency and Some Remedial Measures to Improve Sewage Quality

ELSON T. KILLAM
Consulting Engineer, New York, N.Y.

STUDY of numerous plants indicates that few factors, other than those attributable to industrial wastes, have such predominating effects upon plant operation as does the condition or quality of the sewage upon arrival at the plant. The quality and condition of the raw sewage as it arrives at the treatment works has important effects upon operation, loadings, and efficiency of treatment plant units.

Stale and septic sewage imposes limitations and operational problems beyond the control of the operator, and remedial measures must be applied at the source; in other words, in the tributary system.

Such difficulties may most effectively be avoided or minimized at the time the tributary system is designed, but unfavorable conditions in existing systems may often be effectively improved.

Causes of Septic Conditions

Among the more common causes of spetic conditions are the following:

1. Undesirably flat grades, small flows, uneven alignment and grades, and oversize pipe, all of which are reflected in the lodgment of organic deposits.
2. Oversize pump wells and pump suction arrangements that do not effect adequate dewatering of the well each time the pump operates.
3. Backflooding of main sewers, and reduced velocities, coincident with nonuniform flow, due to too high an elevation of high water in pump wells; due to surcharge from tidal outlets, or due to backflooding of secondary lines from overloaded main sewers.

Results of Foregoing Conditions

The foregoing conditions frequently cause rapid deterioration in sewage quality with important and undesirable consequences, including—

a) Disintegration and liquefaction of solids, with reduction of settleable suspended solids and increase in nonsettleable and dissolved solids.
b) Increase in dissolved and non-settleable B.O.D.
c) Early gasification of solids.
d) Excessive hydrogen sulfide formation with attendant nuisance, deterioration of structures and equipment, or other difficulties.
e) Substantial increase in chlorine demand.

These undesirable changes in condition of sewage cause a reduction in the overall effectiveness and the efficiency of sedimentation; increase the loadings on, and cost of secondary treatment; frequently comprise the principal cause of odor nuisances; increase the cost of chlorination; and, in general, impair the overall efficiency attainable by treatment.

Remedial Measures in Existing Systems

Correction and improvement of conditions in existing systems may be accomplished by various methods.

In this connection it is pertinent to point out that (in a parallel with the ancient axiom of "one rotten apple in the barrel") a few focal points of development of septic conditions can be reflected in predominating changes in overall condition and quality of sewage from the entire tributary system.

In reverse, the correction of conditions of relatively limited scope may result in appreciable benefits.

Various measures which may prove helpful include the following:

1. A comprehensive and routine program of sewer flushing—at least in "trouble areas."
2. Use of flush tanks.
3. Introduction of stream flow at strategic points during dry weather flow periods.
4. Improvement and reduction of size of pump wells.
5. Regulation of range of pump well levels.
6. Prechlorination at "upstream" locations.

Precautions in the Design of New Systems

Among the more important considerations in the design of new sewerage systems are the following:

1. Strict adherence to adequate minimum grade standards.
2. Adoption of pumping for borderline cases.
3. Use of pipe with smooth interior and longer lengths in critical reaches.
4. Use smaller than normal pipe on short dead-ends—where limited flow is anticipated.
5. "Built in" provisions for flushing.
6. Use maximum care during construction to obtain best possible line and grade.
7. Provision of extra drop to maintain velocity at angle manholes.
8. Provide free drop where laterals join larger sewers.
9. Minimize velocity reductions where sizes change.
10. Provide multiple pump units or variable speed pumping, to maintain greatest possible continuity of station output, supplemented by provisions for periodic high velocity flushing.
11. Set pumps down to low water level in well and keep maximum water level below incoming sewer.
12. Avoid oversized force mains.

Reference to Specific Cases

Case (A):

In one study to determine the source of extensive odor complaints it was found that an old pump well—better described as a storage reservoir—increased the chlorine demand from 12 ppm. in the influent to over 30 ppm. as the sewage left the well. The excess chlorination cost for each 1 mgd. flow would amount to over $3,000 per year.

Case (B):

In the absence of certain industrial wastes, the proportion of total volatile solids designated by analysis as suspended volatiles, provide an important indication of the condition of the sewage, i.e., "Stale" or "Fresh."

If a high percentage of volatile solids are settleable, the removal of suspended solids will be high. Of greater importance, the removal of B.O.D. in the primary treatment units will be increased, with consequent reduction of load on the plant's secondary phases of treatment.

In a series of 24-hour tests of a group of sewerage systems in various parts of the country, it was found that the proportion of volatile suspended solids which were settleable, and therefore adaptable to effective treatment by sedimentation, varied from as high as 80 per cent to as low as 36 per cent.

The matter of grades in the tributary systems, the extent of the system, and sewage temperatures account for most of this wide variation in raw sewage character. If we assume that under average conditions approximately 60% of the suspended solids can be removed by sedimentation, it is obviously of basic importance whether 80% of the total organic solids are of a character susceptible to a 60% removal, or whether only 36% of the total are settleable to start with. In other words, 60% of 80% means a removal of 48% of the volatile solids in the first instance, as compared to but 60% of 36% or 22% in the latter case.

Every hundred pounds of B.O.D. that goes down in settleable form which otherwise, after being dissolved would go on to the filters, or to the activated sludge process, represents a very tangible increase in load on the secondary units of the plant.

The comparative conditions in these various systems may be summarized as follows:

System Designation	Description of Salient Features of Collecting System	% Total Volatile Solids Reported as Suspended
A	Small system serving 2,000 population—steep grades—short outfall	80%
B	Another small system in same municipality—similar conditions	76%
C	Small system serving 5,000 population—steep grades—short outfall	65%
D	Large system—serving 100,000 population—steep grades—high velocities in outfall	58%
E	Large system—moderate grades	56%
F	System serving 10,000—some flat grades	48%
G	System serving 8,000 population with some lines on flat grades	48%
H	System serving 8,000 population with large proportion on flat grades	36%

A Clear Cut Experience

In an investigation of a system serving three municipalities with an aggregate population of 60,000, there were indications that the plant was seriously overloaded. It was found, however, that the peak flows, even during extremely severe storms, seldom exceeded twice the average daily flow, and inasmuch as the system involved a long outfall with a low velocity, and there were evidences of septic sewage, a careful study was made of the collecting system and the condition of the raw sewage prior to developing any plans for plant enlargement.

Even in extremely cold weather the sewage was found to be highly septic, with high chlorine demands, excessive hydrogen sulfide content, gasification of sludge in the primary tanks, periodic development of of-

fensive odors, and other undesirable conditions.

It was accordingly recommended that the program for enlargement and improvements be deferred until corrective methods were adopted in the tributary system in an attempt to improve the quality of the raw sewage.

The recommendations included:

a) Resumption of operation of a considerable number of old flush tanks in the system.
b) Establishment of a routine and comprehensive program of sewer flushing.
c) The regulation of pumping levels to avoid surcharge of incoming sewers.
d) Introduction of brook water into the system at times of dry weather flow in order to improve velocities in the main line.
e) Prechlorination.

With the cooperation of the officials of the cities involved, a striking improvement in raw sewage quality was brought about. In fact, the improvement was so pronounced that steps (d) and (e) have not as yet been found necessary.

It is of interest to note that tests prior to the adoption of corrective measures indicated a dissolved volatile content of 280 ppm. Since the corrective measures were instituted, for the past year the average value has been only 147 ppm. This is approximately one-half the dissolved volatile content prevailing prior to the adoption of remedial measures.

The improvement can also be measured by the fact that, for all practical purposes, hydrogen sulfide has been eliminated; the chlorine demand has been reduced by 50%; the development of gas and flotation of sludge in the primary tanks has been practically eliminated; the efficiency of primary sedimentation has been increased from 30% to over 50%, and the load on the trickling filters has been reduced by approximately 30%.

The foregoing examples and similar experience in other instances effectively demonstrates the desirability of careful consideration of design features which may affect sewage quality and indicates the potential effectiveness of remedial measures and "good housekeeping" on existing systems.

RATIO OF SLUDGE DENSITY TO VOLUME

An Important Consideration in Operating

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Chemist
Albright & Friel, Phila., Penna.

THE variation in sludge volumes with solids content changes determines the most effective use of sludge handling and other treatment facilities in a sewage treatment works.

In this all important consideration it is, of course, the amount of liquid mixed with the sludge solids that determines the volume to be handled, and since the volume varies so markedly with the per cent of solid matter contained, this fact has important significance to the sewage works operator and engineer. The effect extends to the operation of digestion tanks, concentration tanks, aeration units, pumping and piping facilities, sludge storage, and other treatment units.

It becomes apparent that all the efforts of a sewage works operator to secure a more concentrated sludge contribute sizeable dividends to plant efficiency and operating expense, when one considers that a rise in moisture content by a mere 2.5% means 100% more liquid volume to be handled per one hundred pounds of sludge solids, when the water content rises from 95% to 97.5%. By the same token a sludge of 99.5% water, as against 97%, has a volume 500% greater. When using, as a base, the same quantity of solids to be handled, a digesting sludge of 95% moisture occupies just one half the space of a sludge of 97.5% moisture. The significance of this matter is that the digestion period of the sludge may be doubled by what may look to be an insignificant decrease of only 2.5% water content. If a sludge with 95% moisture passes through a digester in a theoretical (calculated) time of thirty days, and the sludge becomes thinned to 97.5% moisture, two things happen to give a serious change in digester operation. These are:

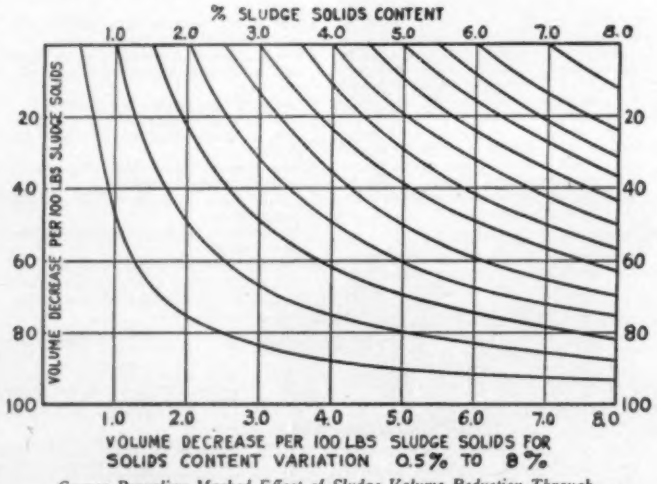
(1) The solids pass through the digester in one-half of the theoretical time (actually more nearly one-quarter of the time, due to disturbance of solids, dilution, and intermixing of new and old solids).

(2) It will require approximately 100% more heat input to maintain a given temperature in the digestion tank because there is twice the volume of liquid to be raised to the desired temperature.

The marked changes due to a combination of these two effects are not hinted in the mere 2.5% more moisture content of the sludge which appears in the operating records. On the other hand if we recorded sludge concentration in terms of pounds of solids per 1000 gals., or the reverse, rather than percent solids, the volume relationship would become very much more evident to us in following operating records.

The relation of moisture content to the volume of sludge handled magnifies itself many times in activated sludge practice. For example, the difference between a sludge of 99.5% and 97% water is represented by a volume reduction of the magnitude of 6 volumes reduced to 1 and is of very real consequence and importance. The meaning of sludge volume decrease to an operator of an activated sludge plant may be easily evaluated upon a careful examination of operating data and any permissible measure of securing sludge concentration has high justification in improved operation and economy.

The accompanying graph shows the relation of sludge volume to solids content variations more fully than any number of words or further examples.



Curves Revealing Marked Effect of Sludge Volume Reduction Through Concentration.

Note that increasing solids content from 0.5% to 3.5% reduces volume to 1/6 original. This in the Activated Sludge Process is of great significance.

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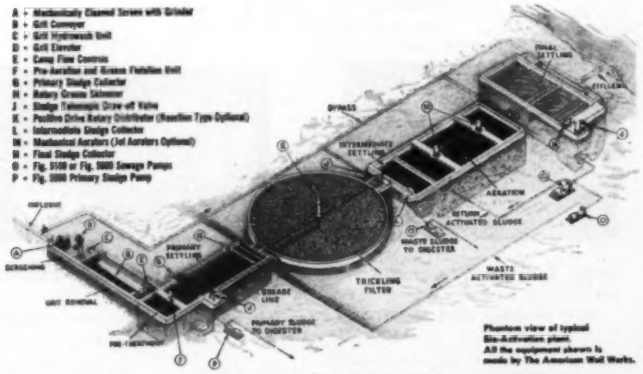

Phantom view of typical Bio-Activation plant. All the equipment shown is made by The American Well Works.

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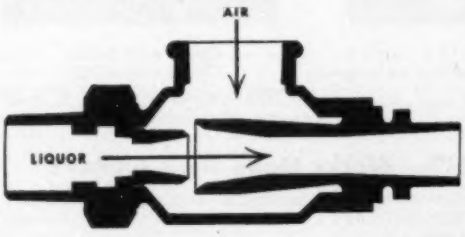
Fully described and illustrated in Manual No. 149.



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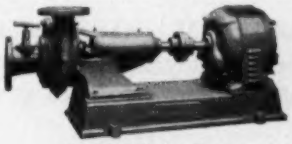

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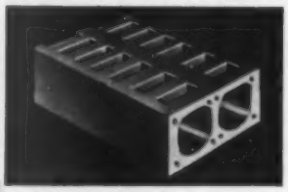

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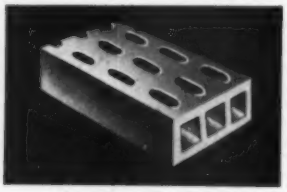
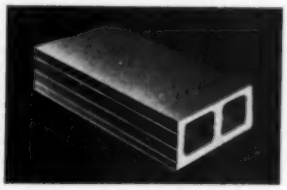
For best results in all standard types of filters.





Cover Plates
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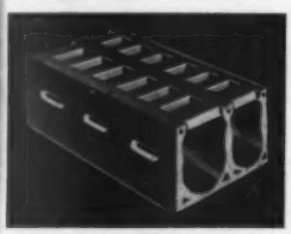
Perforated cover plates and plain for covering drainage channels.



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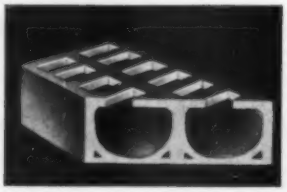

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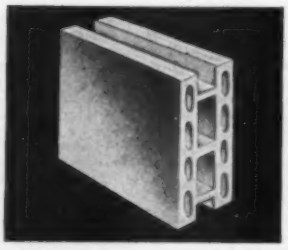
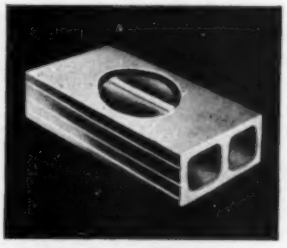


Tank Blocks — 6 x 12 x 12 tank blocks for outside walls of trickling filters.



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HIGH-RATE FILTER PERFORMANCE*

F. W. MOHLMAN
Director of Laboratories,
Sanitary District of Chicago

IT IS unfortunate that the development of high-rate filters has been so competitive, because each company promoting a certain type of filter has been interested in giving publicity to results of operation that apparently show the superiority of the company's type of filter. Certain helpful developments have occurred, such as approximately continuous dosage, recirculation, use of coarser media, uniform volumetric dosage and continuous discharge of flocculated solids, but many of the curves, formulae and assumptions derived from filter operation actually rest upon a deficiency of the B.O.D. determination: namely, that the same 5-day B.O.D. result can be obtained whether or not there is nitrification of the applied ammonia nitrogen.

The writer makes no claim that it is necessary to oxidize the ammonia nitrogen, with reference to conditions of disposal, but from the standpoint of work done by the filter it makes a lot of difference whether the treated effluent is in the first or second stage of the B.O.D. curve, and filter volume giving low rates of application is necessary if one wants to accomplish complete treatment by a filter.

Early Investigations

The Sanitary District of Chicago became interested in high-rate filters in 1935 and Halvorson's filter in Minneapolis was visited, followed by the installation of an experimental 20-ft. filter in Chicago. Later a Jenks two-stage shallow filter was operated for about two years. The summarized results of operation of these filters are shown in Table I.

As the years have passed, numerous contributions have been made by the promoters of high-rate filters, with all possible consideration of the favorable factors. It is quite evident that a renaissance has occurred in the theory of biological filtration as exemplified by trickling filters, namely, the principles of low-rate application of load by nearly continuous coverage of surface "raindrop" application, uniform unloading of solids, thorough secondary settling, recirculation of all varieties, and improved dosing apparatus.

Recent Studies

Many investigations have also been made by disinterested parties, such as the Walton investigations sponsored by the state sanitary engineers of the Upper Mississippi Basin, the summarized results reported by Dreier (Sew. Wks. Jour., July, 1946; *Water and Sewage Works*, Jan., 1947) and the report of the National Research Council on "Sewage Treatment at Military Installations" (Sew. Wks. Jour., Sept., 1946).

The trickling filter results in the latter report were re-arranged in Tables VIII, IX, X and XI of the concluding summary report compiled by the NRC Subcommittee on Sewage Treatment in Military Installations and published in the January, 1948 issue of Sew. Wks. Jour. The tables group the data for four classes of filters: (1) deep, with no recirculation, (2) deep, with recirculation, (3) shallow, with recirculation, and (4) two-stage. The plants are arranged in the order of filtration loads, and some nitrification results are shown. Reference is made to these tables in the following discussion.

TABLE I.—Sanitary District of Chicago High-Rate Filter Studies

Type Filter	Period of Operation	Rate (m.g.a.d.)	Recirculation (%)	Lb. B.O.D. Removed per Acre-Ft.	B.O.D. (p.p.m.)			Susp. Solids (p.p.m.)			Nitrate + Nitrite N (p.p.m.)
					Filter Inf.	Final	Efficiency (%)	Filter Inf.	Final	Efficiency (%)	
Deep	Year 1937	27.7	0	1,187	72	31.1	57	74	31	57	1.8
Shallow	Year 1937	28.7	217	1,079	73	44.3	39	74	54	27	1.9
Deep	Aug.–Dec., 1937	28.3	0	1,198	73	35.2	52	73	28	62	2.5
Shallow	Aug.–Dec., 1937	21.1	231	1,347	73	30.6	58	73	37	49	3.6

At rates of 28 mgad. the B.O.D. in the effluent was 31 to 44 ppm., corresponding to about 50 per cent reduction from the influent, and suspended matter in the settled effluent ran from 28 to 54 ppm. Later, the shallow recirculated filter, at a rate of 21 mgad., yielded an effluent containing 31 ppm. B.O.D. and 37 ppm. susp. solids, removing 1,347 lb. B.O.D. per acre-ft. and producing 3.6 ppm. nitrate plus nitrate nitrogen.

The best of these results, however, was far from satisfying the requirements of dilution imposed upon the District by the Supreme Court, so high-rate filters were abandoned in favor of activated sludge treatment, which produces effluents with only 8 to 15 ppm. B.O.D. and correspondingly low suspended solids.

Table VIII in the summary report (Sew. Wks. Jour., Jan., 1948, page 73) shows the first series. These filters were all about 6 ft. deep and in most cases the load was quite low. Thus they could be classified as standard-rate trickling filters.

At loadings up to 720 lb. per acre-ft., except for the Fort Sheridan filter, the filters plus secondary settling tanks removed 85 to 92 per cent of the applied B.O.D., and the overall removal varied from 91.5 to 95.0 per cent. Fort Sheridan gave anomalous results, showing poor removals probably because of excessive primary settling period, pooling, and high application rates resulting from excessive resting periods. Nozzles discharged only 4.5 minutes out of 25, giving a very high momentary rate.

Nitrification continued quite well up through the loading rate of 377 lb. B.O.D. per acre-ft., but fell off at 429 and especially at 720 lb. per acre-foot. The low degree of nitrification at Ft. Benjamin Harrison—only 1.5 ppm. nitrite plus nitrate nitrogen—appears questionable with the 429 lb. loading, since the ammonia N decreased from 21.1 ppm. in the influent to the filter to only 6.1 ppm. in the filter effluent. Since surely more than 1.5 ppm. of this loss was nitrified it may be concluded that nitrification was active up to 720 lb. loading of B.O.D. per acre-foot.

The second series of filters (Table IX, NRC summary report, Sew. Wks. Jour., Jan., 1948, page 74) shows results for eleven plants, with loadings from 245 to 5,750 lb. per acre-ft., and recirculation of from 24 to 358 per cent of the applied volume. Of the first four plants, Gordon was not very effective in removal of B.O.D. but removal of suspended solids was excellent. Leaving out this plant, the overall removal of B.O.D. was around 93 per cent, up to a loading of 1,170 lb. B.O.D. per acre-foot.

The next four plants were loaded up to 2,000 lb. per acre-ft. and gave decreasing removals and practically no nitrification. Forrest and Jackson, at 2,530 and 2,870 lb. loading, gave decreasing removals, but Callan, at the enormous loading of 5,750 lb., gave good removals. This was the prize camp in operation, possibly due to very good secondary settling, which reduced the B.O.D. from 118 ppm. in the filter effluent to 77 ppm. in the final effluent. Good flocculation and low overflow weir rates were probably responsible for the high removal. The camp was located in Southern California.

Table X in the NRC summary report (Sew. Wks. Jour., Jan., 1948, page 76) shows results for shallow filters, with high rates of recirculation. The four plants, except Kearns, gave poor filter results due to excessive growths of fungus on the filters.

The other three plants gave high B.O.D. removals up to 2,320 lb. loading, but obviously with no nitrification. Kearns gave 11.3 ppm. nitrite plus nitrate N with 792 lb. loading, but with excessive recirculation far beyond the bonds of economy.

The last four plants gave poorer results, down to 58 per cent overall removal (first-stage) at Frances Warren, the most heavily loaded filter included in these studies. This was only the first stage, the final effluent from the second stage being reduced to 66 ppm., an overall removal of 84.8 per cent. Plant efficiency was reduced by return of a heavy supernatant liquor, and also because of the severe Wyoming winter weather.

Results for two-stage filters are given in Table XI of the NRC summary report (Sew. Wks. Jour., Jan., 1948, page 77). These results were all good at moderate loadings except Warren, which was somewhat inferior for reasons given above. With the very high loading of 5,280 lb., Camp Roberts gave quite inferior removals.

Discussion

The individual results in Tables VIII to XI of the NRC summary report have

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TABLE II.—Summary of Trickling Filter Plant Operation

No. Plants	Group Designation	Range of B.O.D. Loading (lb./acre-ft.)	B.O.D. Efficiency, Filter and Sec. Settling (%)	Overall B.O.D. Reduction (%)	B.O.D. Remaining (%)
4	Deep, No Recirc.	253 to 429	86.9	92.2	7.3
4	Deep, Recirc.	245 to 1170	85.7	90.8	9.2
8	Two-Stage	192 to 930[1]	66.5[1]	90.2	9.8
4	Shallow, Recirc.	792 to 2320	81.8	88.1	11.9
4	Deep, Recirc.	1100 to 1950	78.7	87.5	12.5
3	Deep, No Recirc.	720 to 2130	75.7	82.8	17.2
3	Deep, Recirc.	2530 to 5750	70.3	78.3	21.7
4	Shallow, Recirc.	2370 to 8250	70.1	74.8	25.2

[1] Second stage.

been summarized in various groups in Table II, with increasing loadings from 253 to 8,250 lb. per acre-foot. The first group, deep filters without recirculation, gave 93 per cent overall reduction and is characterized by high nitrification and low volumetric and organic loads applied.

Next, recirculation enables the loads to be increased to 1,170 lb. per acre-ft., and in general results improved as recirculation ratios increased. At Boca Raton a filter rate of 14.9 mgad. plus 358 per cent recirculation gave an effluent with only 16 ppm. B.O.D.

Recirculation thus improved considerably results from a deep filter at 1,170 lb. per acre-ft. application, but the rate of recirculation seems too high for such a dilute sewage.

Next, two-stage filters gave excellent results but most of the work was done in the first stage.

For higher loadings, up to around 2,000 lb. per acre-ft., shallow filters with considerable recirculation (from 280 to 1,050 per cent) were able to produce around 90 per cent overall reduction of B.O.D. and, at Kearns, considerable nitrate with the highest rate of recirculation.

A mathematical analysis by Dr. Thomas (Sew. Wks. Jour., Sept., 1946, page 975) indicates that an 800 per cent recirculation rate gives the maximum increase in capacity of high-rate filters.

Finally, at high rates of loading, from 2,370 to 8,250 lb. per acre-ft., results were quite inferior to those produced by a standard low-rate filter.

It is interesting to note that loadings above 2,000 lb. per acre-ft. resulted in effluents containing around 70 ppm. B.O.D., overall removals of 78 per cent, and no nitrification. This is far from the quality of an effluent from standard low-rate filter operation, even though the loading is less than the 3,000-lb. rate used in design of high-rate filters.

None of the filters loaded at over 2,000 lb. B.O.D. per acre-ft. produced nitrification. For the period during which nitrogen tests were made, some of the results are shown below:

It will be noted that the ammonia nitrogen shows very substantial reduction in the lightly loaded plants, with corresponding high nitrates in effluents. For single-stage plants, at loadings in excess of 974 lb., ammonia is reduced very little and there are no nitrates. Two-stage plants show nitrates.

Considerable oxidizing intensity is necessary to promote nitrification. The ammonia present requires 4 oxygen to 1 nitrogen, or 4.56 times the decrease in ammonia nitrogen. This can require considerable air in activated sludge treatment, or filter surfaces, for oxidation, and therefore the dosing rates must be low if nitrification is to occur.

It seems difficult to believe, therefore, that effluents from high-rate filters, dosed at rates higher than 1,000 lb. B.O.D. per acre-ft. per day, are just as completely treated as effluents from standard low-rate filters. There is a fallacy in using only the 5-day B.O.D. to measure the results accomplished.

For many conditions of disposal, however, a nitrified effluent is unnecessary, and for such conditions, intermediate grade effluents will suffice, such as those from chemical treatment as well as from high-rate filters. For Army camps, urgent as well as temporary, such filters were highly satisfactory. Are they as satisfactory for permanent use in municipal installations?

Post	Lb. B.O.D. per Acre-Ft. per Day	Ammonia Nitrogen as N (p.p.m.)		Nitrite + Nitrate N (p.p.m.)
		Influent to Filter	Final Eff.	
Campbell	172	29.1	3.9	17.4
Fitzsimons G. H.	283	19.9	12.1	0.9
Benj. Harrison	199	21.1	6.3	1.5
Swift	197	27.4	9.7	11.8
Leonard Wood	256	44.2	9.2	19.5
Carson	320	14.3	8.0	2.0
Drew Field	974	25.1	18.2	0.9
Jackson	2930	29.0	20.4	0.8
Knox	1563	15.7	13.4	1.9
Bragg	3900	33.5	32.0	Tr.
Kearns AAF[3]	678	26.0	22.0	12.3
Gordon[2]	392	22.6	16.6	5.0
F. E. Warren[2]	980	46.1	21.9	7.0
Claiborne[1]	1040	32.0	24.0	1.2

[1] First-stage.
[2] Two-stage.
[3] Recirculation, 1,050 per cent.

HIGH-RATE FILTER PERFORMANCE—A DISCUSSION

W. A. HARDENBERGH
Editor
Public Works Magazine, New York City

THE performance of high-rate trickling filters is a matter of record. Somewhat over a hundred such filters were built to serve military establishments during the war. On these, there are available the excellent data prepared by the National Research Council Sub-Committee on Sewage Treatment at Military Installations (1). Operation records on many of the high-rate filters used by municipalities and industries are also available, but these data are not generally so complete and authentic as those from the military establishments.

There are four types of high-rate filters. They are described, in the words of the manufacturers or their representatives, as follows:

"Biofilter (2) is a term applied to high-rate filters, normally comparatively shallow, which employ . . . the recirculation of all or part of the filter discharge back to the detention tank. The recirculated filter discharge may be filter effluent, or secondary clarifier contents, underflow or effluent."

Aero-Filters are "one classification of the 'high-rate' trickling filter group" having "a low momentary rate of sewage application whereby a high daily capacity for B.O.D. reduction is obtained." This process (3) "applies the sewage over the media in a very thin film. . . ." In the Aero-Filter recirculation is used at periods of low sewage flow in order to maintain a minimum necessary rate of application at which the distributor will function properly; it is also beneficial for treating strong wastes.

"The Accelo-Filter system (4) involves the direct recirculation of unsettled effluent from a biological filter back to the inlet of the filter distributor. This process may be used with either low-rate or high-rate filters."

"Reversible double filtration (5) consists of two trickling filters arranged to be operated for two-stage filtration with provision for reversing the sequence of the filters so that each may alternately serve as the primary and the secondary filter. This will allow the primary filter to be utilized with maximum effectiveness by applying, for short periods, loadings approaching the limit of the capacity of the filter. The secondary filter meanwhile will operate under much reduced loadings. . . ."

Loadings for high-rate filters are now quite well established in the range of 3 lb. of raw sewage B.O.D. per cubic yard of stone per day. With the reduction obtained by primary treatment, the applied B.O.D. is generally designed to be a little

less than 2 lb. per cu. yd. or about 3,000 lb. per acre-foot. There is evidence, however, that heavier loadings are possible when recirculation is employed. In the experimental work done by the U. S. Public Health Service at Neosho, Mo., loadings in excess of 2.5 lb. of B.O.D. per cu. yd. were applied with no indication of a break from the straightline trend of removal. Banister and Ellison (6), using tile media for the treatment of strong sewages containing milk, packing and canning wastes, report a normal loading of 3.3 lb. of B.O.D. per cu. yd. of media with a B.O.D. removal of 70 to 75 per cent; and nearly straightline removals up to 6 lb. or more per cubic yard. With stone media, they report a critical loading of about 4.5 lb. of B.O.D. per cu. yd., with removal consistently less than for tile.

Two of the plants noted in the NRC report were loaded considerably higher than the limits indicated above. Camp Callan, a deep filter employing recirculation, had an average applied loading of 5,750 lb. per acre-ft. or more than 3.5 lb. per cubic yard. Removal was 4,280 lb. per acre-ft., or 74.5 per cent. The Fort Bragg filter, a shallow unit, had an applied load of 4,340 lb. of B.O.D. per acre-ft., or about 2.7 lb. per cu. yd., and gave a removal of 80.7 per cent. Both of these plants employed recirculation. The Great Lakes plant, a deep filter without recirculation, had a loading of 2,130 lb. per acre-ft., or 1.3 lb. per cubic yard. Removal was 71 per cent.

Since B.O.D. removal is proportional to the load applied, a higher B.O.D. loading will always result in an effluent containing a higher concentration of B.O.D. This applies to any particular process, but by means of recirculation or two-stage treatment much better results can be obtained than with a single passage of the sewage through the filter. Single-stage high-rate filters without recirculation may accomplish a removal of 70 per cent of the applied B.O.D., or sometimes a little better. With an applied sewage of 200 ppm., this means an effluent with about 60 ppm. To obtain an effluent containing only 30 ppm. of B.O.D., with the relatively standard loading of 3,000 lb. per acre-ft., or 1.86 lb. per cu. yd., recirculation is necessary. According to Gloppen (3), in order to maintain an effluent of 30 ppm. B.O.D., the applied sewage should not exceed 135 ppm. B.O.D. Normally recirculation will be required to dilute the settled sewage to this strength.

Two-stage treatment will accomplish remarkable results, even with heavy loadings. Camp Roberts (1), with a loading of 8,680 lb. per acre-ft., or more than 5 lb. per cu. yd. of filter media, produced an effluent with an average strength of 53 ppm.; Fort Warren with a loading of 8,520 lb. per acre-ft. produced an effluent with 66 ppm.; and Fort Sill, with a loading of 6,440 lb., or 4 lb. per cu. yd., had an effluent with 26 ppm. of B.O.D.

The 1-mgd. plant at Liberty, N.Y., a two-stage biofilter, was designed to handle a raw sewage loading of 3.1 lb. per cu. yd. of media. In July, 1944, the average flow was 1.29 mgd.; the average raw sewage B.O.D., based on composites from 8 a.m. to 2 p.m., was 520 ppm., representing a 24-hour composite of probably 360 to 370 ppm.; and the average effluent from the secondary clarifier (9 a.m. to 3 p.m. composite) contained 21 ppm. B.O.D. The actual effluent B.O.D. content during this month averaged slightly less than 6 ppm., the secondary clarifier effluent being passed through a magnetite filter and chlorinated before discharge into the stream. The results for 1944 are about the same as those that have been attained consistently ever since the plant was put into operation in the fall of 1940. Operation is by one man, which accounts for the daytime tests. During the winter, the plant is operated without recirculation as a conventional trickling filter, with satisfactory results, since the population load is then much lower, Liberty being a summer resort.

There is a need for more knowledge about the requirements for underdrainage and ventilation in filters. Certainly, adequate provision should be made to remove the liquid promptly and to provide air to the bed, not only when the plant is new but also after it has been in service for many years and has accumulated a considerable organic growth. Those who have had the experience of removing the stone from an old filter will appreciate the amount of material that is found in them, especially in the bottom few inches through which the filtrate must pass and air must enter.

Pretreatment should be the best that can be provided. Anything that can be removed by settling results in that much less load on the secondary treatment units. The necessity for good design and adequate provision in final settling is just as great. It is well to remember that the clarifier following the filter is essentially a part of it, and must do its share in removing the settleable material in the filter effluent.

Media size and type for best treatment results have not been determined. A careful study of filter operating results does not give any conclusive basis for design. There is general agreement that the stone should not be too small, nor too large. Probably 2½- to 3½-in. or 3- to 4-in. represents good general practice and is desirable. The writer's preference would be for the larger stone, even in the secondary units of two-stage filters. Tile media have not been widely used, but should certainly be considered for strong sewages. According to Banister and Ellison (6), tile block is a "uniform material, permanent in character and self-cleaning. It will not pond. The normal design loading for a tile media high-rate filter is about 3.33 lb. per cu. yd. of media, permitting the use of a unit 10 per cent of the size of a low-rate filter. . . . The small size . . . permits economical housing, thus providing odor control, fly control and better treatment during the winter months." When a high degree of treatment is required and the final effluent must have a low B.O.D. content, these high-rate filters are followed by low-rate filters with stone media.

It is likely that two-stage filtration will become more general, with the use of high-rate filters as roughing filters carrying a very heavy load, and with final treatment by secondary high-rate filters, low-rate filters or activated sludge. All these methods are now in use, and with good results. The selection among them should be largely a matter of local conditions.

It appears reasonable to say, as regards high-rate filters, that a sound basis for design exists, but there is no explanation of the fact that some installations perform in a superior manner. It has been a matter of interest to the writer to investigate much of the data available to determine whether media size, underdrainage provisions, the character of the water as respects pH and alkalinity, and various other factors might have an important influence. None of these, with the possible exception of underdrainage and ventilation, appears to have any effect on the quality of the effluent from a trickling filter.

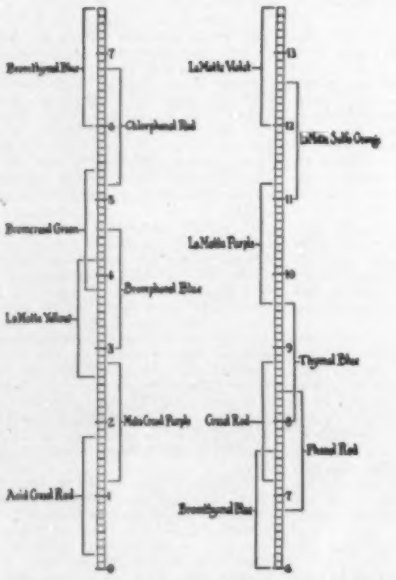
Perhaps it goes back to what F. H. Waring terms the "treatability of the sewage." That may be reflected in the B.O.D. characteristics of the sewage and the rate of biochemical oxidation. The NRC report brought out the varying values of k in military sewages. The average value of k for domestic sewage is 0.10, but the average value for the sewages at 16 military posts was 0.18. With k equal to 0.10, the 5-day B.O.D. represents 68 per cent of the ultimate B.O.D., but when k equals 0.18, the 5-day B.O.D. represents 87.4 per cent of the ultimate.

Thus, the B.O.D. test may be a varying rule for measuring operating characteristics, with naturally varying results. It seems unlikely, however, that this is the sole reason for the variations in performance noted at different plants. Uniformity of loading and of sewage application is probably a factor of at least some importance. Study of the other factors in design or operation that so markedly influence operating results furnishes an enticing field for future research and investigation.

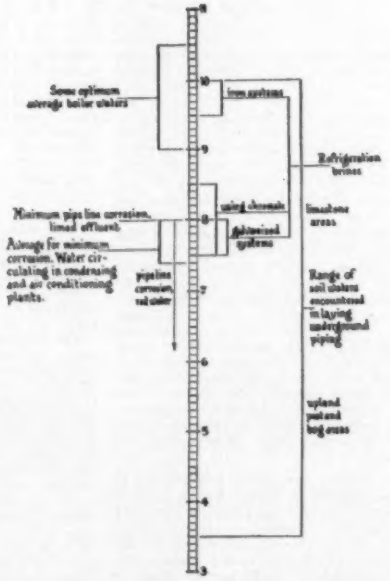
References

1. Sew. Wks. Jour. 18, 5 (Sept., 1946).
2. *Public Works*, 78, 5 (May, 1947).
3. *Ibid.*, 6 (June, 1947).
4. *Ibid.*, 7 (July, 1947).
5. Unpublished data, Pacific Flush Tank Co.
6. *Public Works*, 78, 9 (Sept. 1947).

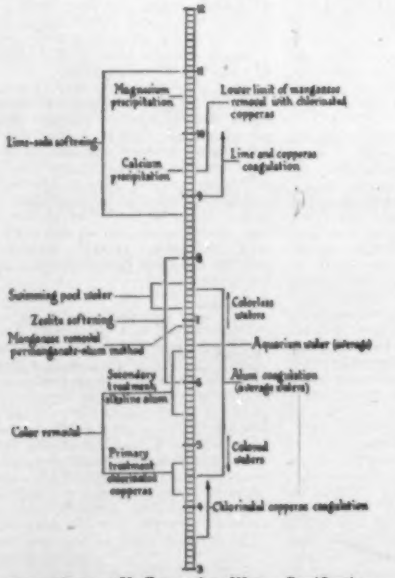
pH ZONES OF IMPORT IN WATER SUPPLY AND SEWAGE TREATMENT PRACTICE *



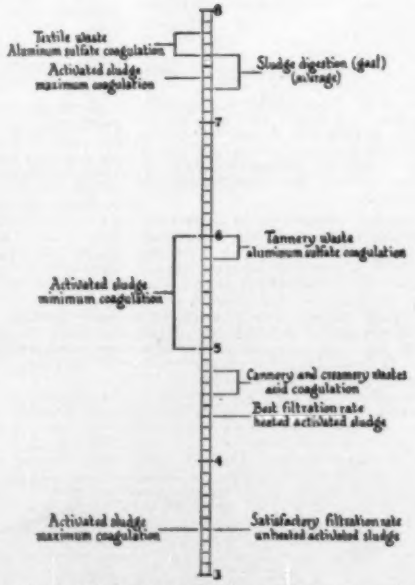
Ranges of Selected Indicators for pH Determination


Some optimum storage boiler waters
Iron systems
Refrigeration brines
using chromate
Minimum pipe line corrosion, limed effluent
Aerated
deaerated systems
limestone areas
Aerage for minimum corrosion. Water circulating in condensing and air conditioning plants.
pipeline corrosion, soil water
Range of soil waters encountered in laying underground piping
upland peat and bog areas

Approximate pH Zones Encountered in Common Corrosion Problems



Approximate pH Zones for Water Purification


Textile waste
Aluminum sulfate coagulation
Activated sludge maximum coagulation
Sludge digestion (goal) (average)
Tannery waste aluminum sulfate coagulation
Activated sludge minimum coagulation
Cannery and creamery wastes and coagulation
Best filtration rate heated activated sludge
Activated sludge maximum coagulation
Satisfactory filtration rate unheated activated sludge

Approximate pH Zones for Treatment of Sewages and Some Industrial Wastes

*Reproduced from the reference work "pH and Its Practical Application"—LaMotte, Kenny & Reed—(Williams and Wilkins, Publishers, Baltimore, Md.)

UTILIZATION OF CHLORINE DURING SEPTICIZATION OF SEWAGE*

by H. HEUKELEKIAN

Assoc., Dept. of Sanitation, Rutgers University, New Brunswick, N. J.

HYDROGEN sulfide is the main source of odors derived from sewage. It arises from the reduction of sulfates by certain bacteria under anaerobic conditions. Chlorine is widely used as a means of control of such odors. As a preventive measure, it is generally added to sewage before sulfides are produced and acts by retarding the septic action. Under these conditions relatively small doses of chlorine are sufficient. Seldom is it necessary to obtain a residual chlorine to delay the action. Experimental work reported previously[1] has shown that chlorine dosage as low as 20-25 per cent of the full chlorine demand is sufficient to delay sulfide production.

When sewage becomes septic before chlorine is applied, it is to be expected that a greater dosage will be required to destroy the odors produced, because the chlorine demand of septic sewage is higher than that of fresh sewage. The effectiveness of the chlorine when applied as a remedial measure depends on the reaction between the chlorine added and the hydrogen sulfide present. If there were no other substances in sewage reacting with the chlorine other than hydrogen sulfide, then a dosage of chlorine sufficient to react with the sulfide would be necessary.

Inasmuch as the concentration of hydrogen sulfide seldom reaches more than a few parts per million in a sewage which is considered septic and objectionable, the dosage of chlorine should not be high, if it reacted only with the sulfides. Even a fresh sewage, however, has a relatively high chlorine demand, and this demand increases as the sewage becomes septic. It is reasonable, therefore, to conclude that chlorine consumption by hydrogen sulfide represents only a part of the total demand. By measuring the quantity of sulfide destroyed by a given dosage of chlorine, it should be possible to determine the quantity of substances other than sulfides reacting with chlorine and to measure the relative percentage of chlorine consumed by sulfides as against that reacting with other substances during the septicization of sewage. This represents the theoretical aspect of the purpose of the paper. On a practical level, it is the intention of the paper to show the dosage of chlorine required when used as a remedial measure to destroy the sulfides in septic sewage.

Experimental Studies

A number of bottels were filled completely with fresh sewage, tightly stoppered, and, incubated at 20° C., and at intervals one bottle was used for the determination of the chlorine demand, hydrogen sulfide and fixed sulfides.

Various portions of the sewage were then chlorinated to obtain the following percentages of the chlorine demand: 25, 50, 75, and 100. The residual hydrogen sulfide and fixed sulfides were then determined.

Results

The results obtained on the chlorine demand of the sewage and the quantity of sulfides during the incubation period are given in Table I. From the quantities of total sulfides found, the chlorine equivalents were calculated. These equivalents, in turn, are presented as the percentages of the total demand. The differences between the chlorine equivalent of the total sulfides and the total chlorine demand are presented as ppm., and also as percentages of the chlorine demand not accounted for by sulfides.

TABLE I

Chlorine Demand, Sulfides, And Chlorine Equivalent of Sulfides in Sewage Under Septic Action

Days	Chlorine Demand ppm.	H_2S as S ppm.	Fixed Sulfides as S ppm.	Chlorine Equivalent of Total Sulfides ppm.	Chlorine Equivalent of Total Sulfides %	Cl₂ Demand Not Accounted for By Sulfides ppm.	Cl₂ Demand Not Accounted for By Sulfides %
Initial	17.0	0	0.5	1.1	6.0	15.9	94
4	64.5	7.0	1.0	17.6	27.0	46.4	73
7	102.0	8.8	1.4	22.4	22.0	79.6	78
10	316.0	11.6	1.3	28.4	24.0	87.6	76
14	114.0	12.2	1.0	29.0	25.0	85.0	75

The results show that the chlorine demand of the sewage increased rapidly during the first ten days. During this period the hydrogen sulfides content increased simultaneously, while the fixed sulfides remained at a low level. In the fresh sewage the total sulfides constituted only 6 per cent of the chlorine demand, and other reducing substances amounted to 94 per cent of the chlorine demand. As the sewage became septic, between 22 and 27 per cent of the chlorine demand was due to sulfides and 73 to 78 per cent to other reducing substances. The quantity of substances other than sulfides reacting with chlorine was higher than that of the sulfides.

The effectiveness of the addition of various dosages of chlorine, represented as percentage of the chlorine demand, in destroying the hydrogen sulfide and fixed sulfides in sewage which had previously undergone septic action is shown in Table II. It can be seen that only when 100 per cent of the chlorine demand is satisfied, are the sulfides completely eliminated. Chlorination to 75 per cent of the demand left only traces of sulfides, but 50 and 25 per cent chlorination proved inadequate to remove the sulfides from sewage once it has become spetic.

The total sulfides eliminated by chlorine treatment were converted to their chlorine equivalents and the percentages of chlorine added which had reacted with the sulfides were calculated and are given in Table III.

When the sewage was chlorinated to a residual, 22 to 27 per cent of the chlorine reacted with sulfides and the remainder reacted with other substances. With decreasing dosages of chlorine the percentage of the chlorine added which reacted with sulfides increased somewhat. When 25 per cent of the chlorine demand was satisfied, 32 to 38 per cent of the chlorine added reacted with the sulfides. It appears that when the quantity of chlorine added is limited, a greater percentage of the chlorine reacts with the sulfides, indicating that the reactivity of the sulfides

TABLE II

Elimination of Hydrogen Sulfide by Various Dosages of Chlorine Expressed as Per Cent of the Demand

Days	Per Cent of Chlorine Demand Satisfied 100% H_2S as S ppm.	100% Fixed Suf. as S ppm.	75% H_2S as S ppm.	75% Fixed Sulf. as S ppm.	50% H_2S as S ppm.	50% Fixed Sulf. as S ppm.	25% H_2S as S ppm.	25% Fixed Sulf. as S ppm.	0% as S H_2S ppm.	0% ppm. Sulf. as S ppm.
Initial	...	...	...	...	...	...	...	...	0	.5
4	0	0	0.3	0.3	2.1	0.8	4.2	1.0	7.0	1.0
7	0.1	0	0.4	0.7	3.2	1.0	5.4	1.0	8.8	1.4
10	0	0	0.8	0.7	4.6	1.0	7.5	1.1	11.6	1.3
14	0	0	0.5	0.6	4.5	0.9	7.8	1.0	12.2	1.0

TABLE III

PERCENTAGE OF VARIOUS DOSAGES OF CHLORINE ADDED REACTING WITH SULFIDES

Days	Per Cent of Chlorine Demand Satisfied 100%	75%	50%	25%
4	27	33	35	38
7	22	26	26	33
10	24	29	27	32
14	25	31	30	34

*Journal Series Paper of the New Jersey Agricultural Experiment Station, Department of Sanitation, Rutgers University, New Brunswick, New Jersey. Presented before the American Chemical Society, April, 1946, and released for publication in *Water & Sewage Works.*

with chlorine is greater than that of the other reducing substances present in septic sewage.

Discussion

In fresh sewage with only traces of sulfides present the bulk of the chlorine demand is due to substances other than sulfides. As the sewage becomes septic, both the chlorine demand and the hydrogen sulfide increase. Although the rate of hydrogen sulfide production is higher and therefore the chlorine demand of the sulfides is higher than in the fresh sewage, the quantity of chlorine demand represented by the sulfides is only about one-quarter of the total demand. Thus, during septicization both sulfides and other substances reacting with chlorine increase and contribute to the high chlorine demand.

To eliminate the hydrogen sulfide produced during the septic action, the chlorine dosage should be equivalent to 75 per cent of the demand as compared with 20 to 25 per cent required to prevent the production of hydrogen sulfide. On the basis of sewage used in this experiment, the dosage of chlorine required to prevent hydrogen sulfied production as compared with that required to elimiante it after being produced would be as follows:

1. Fresh sewage with 17 ppm., chlorine demand with 25 per cent of the demand satisfied requires only 4.2 ppm. of chlorine.
2. Septic sewage with 8 ppm. sulfides and 64 ppm. chlorine demand with 75 per cent of the demand satisfied requires 48.0 ppm. of chlorine. Thus the chlorine dosage required after sewage has become septic is more than ten times as high as in fresh sewage.

Conclusions

The elimination of hydrogen sulfide odors of sewage after they are produced by septic action required nearly 10 times as much chlorine as the addition of chlorine to prevent their formation.

The reason for this is that 75 per cent of the demand has to be satisfied to eliminate the hydrogen sulfide as compared with the 25 per cent required to prevent its formation. In addition, the chlorine demand increases in septic sewage by virtue of the increases in hydrogen sulfide and the increase in other substances which react with the chlorine. The dosage of chlorine required to combine with sulfides is only one-quarter of the total demand.

Addendum

Pomeroy & Bowlus, in a report[2] published after this paper was presented, have arrived at chlorine applied to sulfide destroyed ratios of 3 to 9, averaging 5.3. The results reported in the present paper give the following ratios:

The ratios obtained varied from 7.2 to 9.1 and are somewhat higher than average, but well within the range given by these authors for results obtained from sewer tests. They indicate that in bottle experiments the ratios may be somewhat lower.

On the basis of these ratios, Pomeroy & Bowlus conclude that it is more economical to destroy the sulfides after they are formed than to prevent their generation. The results presented in this paper are in contradiction to that conclusion. Under practical conditions to reduce the number of chlorinators, Pomeroy & Bowlus favor a compromise, namely, to destroy the sulfides and to use a moderate excess of chlorine to prevent sulfide formation in the sewer for 2 to 3 miles downstream. Complete prevention of sulfide formation by destroying the organisms in the sludge deposits and slimes, is according to the authors, theoretically attractive, but under practical conditions not always successful nor more economical.

Days	Chlorine Demand ppm.	H_2S ppm.	Chlorine Dosage* ppm.	H_2S Resid. ppm.	Ratio Cl_2 Applied: H_2S Destroyed
4	64.5	7.0	48.4	.3	7.2
7	102	8.8	76.5	.4	9.1
10	116	11.6	87.0	.8	8.1
14	114	12.2	85.5	.5	7.3

*On the basis of 75% of the demand.

References

[1]H. Heukelekian, "Sewage Chlorination for Odor Control," *Water Works and Sewerage*, Vol. 89, Pg. 302 (1942).

[2]Pomeroy, R., and Bowlus, F. D., "Progress Report on Sulfide Control," *Sewage Works Jour.* **18**, 597, 1946.

MAKING PIPE BUSHINGS FROM STANDARD PIPE

A Handy Kink

DO YOU know that first class pipe bushings can be made out of standard pipe? Many users of pipe don't know that it can be done. Or, if they know that it can be done they don't know the correct size of drill to use for tapping. I have occasionally made bushings out of pipe, but each time I found it necessary to first look into my handbook for the drill size to use and that is so much trouble that it is frequently easier to go to the store and buy a new bushing. Recently, though, I collected all of the data together for all bushings that can be made out of ordinary sizes of extra heavy and double extra heavy piping, compiled the figures in tabular form, and here they are.

For example, to bush from ¼" to ⅛" get a piece of ¼" extra heavy pipe sufficiently long for cutting the outside thread. Then cut the end off to the desired length, drill or ream with a 21/64" drill (diameter of drill 0.328") and then tap with a ⅛" pipe tap. That's all there is to it.

This accompanying table tells the complete story for all ordinary sizes: Note that in one case, ⅜" to ¼", the internal diameter of ⅜" extra heavy pipe is such that no drilling is necessary.

Note also that in bushing from ½" to ⅜" either extra heavy or double extra heavy piping can be used.

To Bush From	Use This Size Pipe	Use This Size Drill or Reamer
¼" to ⅛"	¼" X	21/64" drill = 0.328"
⅜" to ¼"	⅜" X	None.
½" to ⅛"	½" XX	21/64" drill = 0.328"
½" to ¼"	½" XX	27/64" drill = 0.422"
½" to ⅜"	½" XX	9/16" drill = 0.562"
½" to ⅜"	½" X	9/16" drill = 0.562"
¾" to ⅜"	¾" XX	9/16" drill = 0.562"
¾" to ½"	¾" XX	11/16" drill = 0.688"
1 " to ¾"	1 " XX	29/32" drill = 0.907"
1¼" to 1 "	1¼" XX	1/18" drill = 1.125"
1½" to 1 "	1½" XX	1/18" drill = 1.125"
1½" to 1¼"	1½" XX	1-15/32" drill = 1.468"
2 " to 1½"	2 " XX	1-23/32" drill = 1.72 "
2½" to 2 "	2½" XX	2- 3/16" drill = 2.187"
3 " to 2½"	3 " XX	2- 9/16" drill = 2.562"
3½" to 3 "	3½" XX	3- 3/16" drill = 3.187"
4 " to 3½"	4 " XX	3-11/16" drill = 3.688"
4½" to 4 "	4½" XX	4- 3/16" drill = 4.187"
	X = extra heavy pipe. XX = double extra heavy pipe.	

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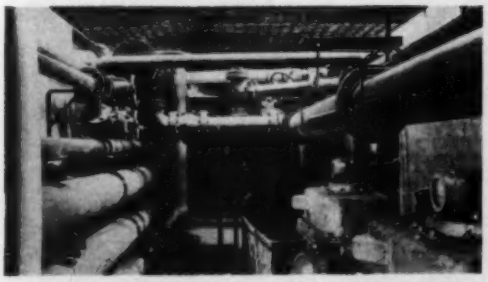

In this sewage installation, Ace hard rubber lined pipe, valves, fittings; Ace solid hard rubber pipe and fittings, and an Ace rubber-lined tank were used for maximum corrosion resistance.

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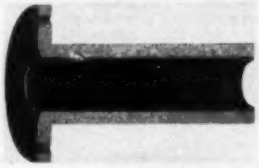

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64 PAGE CATALOG →

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ODOR CONTROL

The control of obnoxious odors from sewage treatment works, long outfall sewers and other disposal plant appurtenances is distinctly a field for chlorination. Neutralization of hydrogen sulfide (the gas responsible for these obnoxious odors), or prevention of its formation by controlled application of chlorine, is not only quite practicable but also results in economy of operation due to reduction of deterioration in interceptors and allied appurtenances.

B.O.D. REDUCTION

Treatment plants discharging effluents into water courses having extreme seasonal variation in flow have profited from controlled chlorination to reduce biochemical oxygen demand. Field tests have often shown a reduction in the five day B.O.D. of up to 30 per cent.

OTHER ADVANTAGES

Similarly, chlorine prevents filter "ponding." It is also widely used to prevent sludge "bulking." Where grease is a problem, chlorine will aid in its removal and minimize its accumulation in small pipes and spray heads. When added to return supernatant liquor from digesters, chlorine tends to counteract the impact of highly putrefactive liquids from fresh sewage. The thickening of sludge may be greatly benefited by the maintenance of a "chlorine blanket" in the supernatant above the sludge. Chlorine is also useful in the preparation of coagulants such as "chlorinated copperas." Difficult trade wastes, such as those containing cyanides, can be effectively purified by designing means for the application of chlorine into the process.

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AUTOMATIC CONTROL OF RAW SEWAGE CHLORINATION

Experiences at Fort Wayne, Indiana

RALPH A. HOOT
Superintendent
Sewage Treatment Works, Fort Wayne, Ind.

THE FORT Wayne Sewage Treatment Works is a conventional activated sludge plant consisting of grit removal, primary settling, aeration and final settling.

Chlorination Essential

Adequate and effective odor control at Fort Wayne is a "must" item. This follows because the plant is located within "olfactory" distance of a number of residences and was placed where it is with the assurance of city officials that the plant could be operated without being a nuisance.

Furthermore, a baseball diamond is located immediately adjoining sewage plant property, with its, at times, spot attendance of 2 to 3 thousand people; and the Fort Wayne entry in the All-American Girls' Baseball League with its 90,000 seasonal customers play but a few hundred feet away. Consequently, adequate, effective odor control is an absolute requirement for this plant.

Two-Stage Process

Sewage chlorination at Fort Wayne is a two-stage process in which part of the chlorine is added to the main interceptor about an hour ahead of the plant and the remainder is added at the plant proper. The first of these stations is called a program station because the chlorine dosage there follows a definite pattern, whereas the second or plant station is the automatic one. At the plant the chlorine is applied at the outlet of the main interceptor which is also the inlet to the grit chamber.

Chlorination is resorted to only during the warm summer months of June, July, August and September and is solely for odor control. The normal application is around 1500 pounds per day with about one half of this being added at each station.

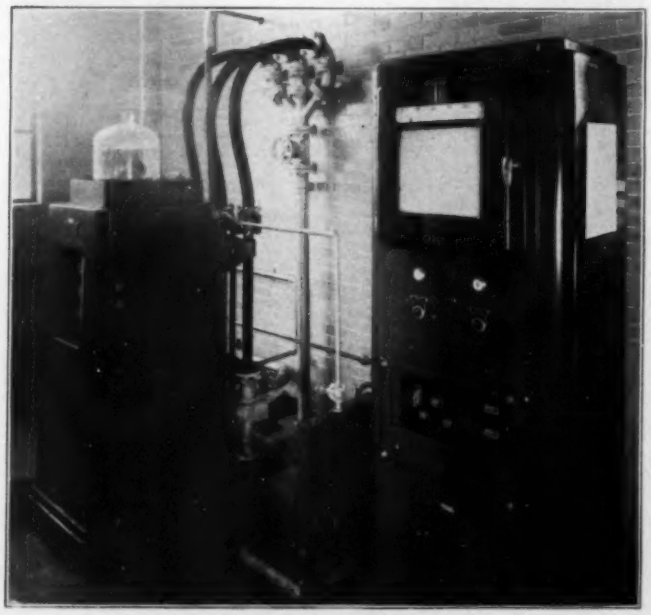
Program Station

The program station is relatively simple. In addition to the tank scales and the ton containers, it consists of the well known Wallace and Tiernan vacuum type chlorinator of 2000-pound capacity, a station rate controller with solenoid operated air valves, and an interval timer. The interval timer makes possible the periodic operation of the solenoid valves which, in turn, increase or decrease the vacuum of the chlorinator, thus increasing or decreasing the rate of chlorine dosage. The interval timer has four settings which make possible four chlorine changes in a twenty-four hour cycle. Generally changes are effected at 2 a.m., 10 a.m., 5 p.m., and 10 p.m., and normally the rate of dosage is 200 lb., 2 to 10 a.m.; 1500 lb., 10 a.m. to 5 p.m.; 1200 lb., 5 p.m. to 10 p.m., and 200 lb., 10 p.m. to 2 a.m. As stated, these rates give a chlorine application at the program station of about one-half the total chlorine required.

Automatic Station

In contrast to the program station the automatic station at the plant proper is quite complicated. In addition to the tank scales and the ton containers this station consists of a potential cell; a Leeds and Northrup recording potentiometer; an automatic rate controller; a W & T vacuum type chlorinator of 2000-lb. capacity; and a rate recorder.

As stated, it is the function of this station to automatically supply the residue of the chlorine requirement not supplied by the program station. Since chlorination is carried to a point 30 to 35 per cent short of an immediate residual, it is the function of this station to add chlorine to maintain that negative residual. In other words, chlorination at Fort Wayne is pursued until 65-70 per cent of the chlorine demand is satisfied with approximately one-half of the chlorine dosage being programmed at the first station and the remainder automatically applied at the second.



Automatic Chlorination Control Equipment

Automatic Control

In a short article it is not possible to give the full details of what takes place when the automatic control process goes into action, but while the system is too complicated for a full technical description, here are four steps which cover descriptively, at least, the sequence of operations.

1. Fort Wayne sewage normally has a rather high chlorine demand. As measured by the Leeds and Northrup potentiometer, Fort Wayne sewage gives a negative difference of potential reading of about 200 millivolts. As chlorine is added and the chlorine demand decreases, the negative millivolt reading also decreases until it passes zero and proceeds into the positive range. At a millivolt reading of positive 200 plus-minus, the immediate chlorine demand of the sewage is just about satisfied.

2. Following chlorination a small stream of the chlorinated sewage is continuously passed through the potential cell and the difference of potential of the sewage as measured by the cell is transmitted to the potentiometer.

3. The potentiometer is set for a millivolt reading of 70. That is to say the potentiometer operates to maintain that voltage at this potential cell. When that coltage is maintained at the cell, 65-70 per cent of the instantaneous chlorine demand is satisfied. If the difference of potential is less than 70 millivolts, the potentiometer "calls" for more chlorine. If the difference of potential is greater than 70, the instrument "calls" for less chlorine.

4. The chlorine call, in turn, is transmitted electrically to the automatic rate controller. If the call is for more chlorine a reversible motor turns in such a way as to increase the submergence of the vacuum tube, thus producing a greater vacuum on the chlorinator and increasing the chlorine dose. On the other hand, if the call is for less chlorine, the motor turns in the opposite direction decreasing the vacuum and likewise the chlorine feedage.

There are two additional steps. In the first place, the potential cell is about 3 minutes away from the point of chlorine application; consequently, in order to give one change a chance to be effective before the next change occurs, the chlorine adjustment is on a 4-minute cycle. Actually the recording of the difference of potential is continuous but via an interrupter; the transmission of the call from the potentiometer to the rate controller is on the 4 minute basis. This cycle is adjustable and if the potential cell were closer to the point of application it

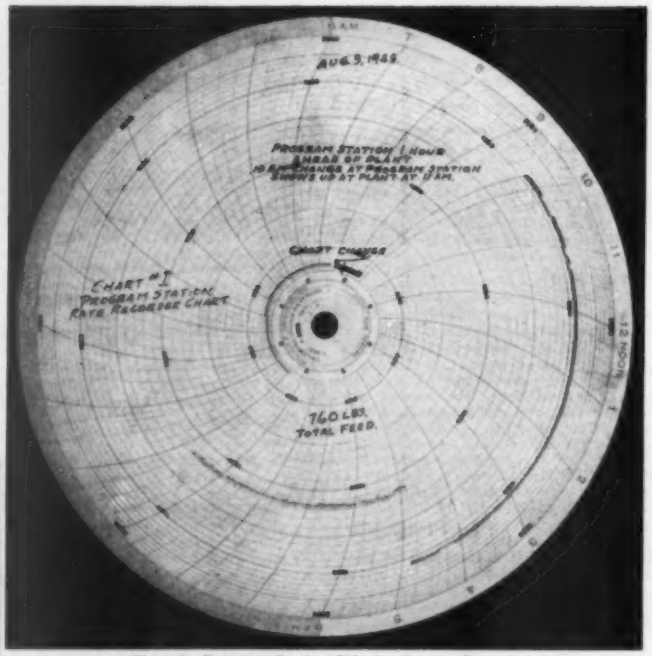

A.M.
AUG. 3, 1945
PROGRAM STATION 1 HOUR AHEAD OF PLANT
10 REVOLUTIONS AT PROGRAM STATION SHOWS UP AT PLANT AT 11 A.M.
CHART CHANGES
CHART #1
PROGRAM STATION RATE RECORDER CHART
760 LBS. TOTAL FEED
12 NOON

Chart I—Program Station Chlorine Dosage Record

could be made more frequent or vice versa.

Secondly, the maximum change which can be effected per cycle is 50 lb. of chlorine. This amount is also adjustable but 50 lb. increments of change work out to good advantage for Ft. Wayne. Hence, if the chlorine feedage at any instant is 100 lb. too high the entire 100 pounds will not be corrected in one jump but will proceed in steps of 50 lb. each.

Operating Charts

Operating charts show quite clearly the procedure of chlorination control. In examining these charts, recall that Fort Wayne's chlorination procedure is a two-stage process of approximately one-half the chlorine requirement at the program station, the other half at the automatic control station; that the automatic control devices are set to maintain a difference of potential of 70 millivolts on the chlorinated sewage or 30 to 35 per cent short of an immediate residual, and that the automatic changes are on a four-minute cycle of 50 lb. maximum changes.

Chart I shows the chlorine rate recorder chart at the program station for August 3, 1945. 200 lb., 2:00-9:45 a.m.; 1550 lb., 9:45 a.m.-4:50 p.m.; 1100 lb., 4:50-9:45 p.m.; and 150 lb., 9:45 p.m.-2 a.m. Total programmed for the day, 760 lb.

Chart II shows the chlorine rate recorder chart at the automatic station for the same date. Chlorine changes every 4 minutes with chlorine rates varying from zero at 6:50 a.m. to 1425 pounds at 10:45 a.m. Total automatic chlorine, 760 lb.

Chart III shows the continuous recording of the millivolt reading on the potentiometer for Aug. 3, 1945, with the dotted line representing the potentiometer setting of 70 millivolts. Negative millivolts not recorded —instrument stops at zero.

The following interesting information can be picked off: (a) the 8 to 9 a.m. chlorine increase at the automatic station shows the effect of the increased morning load. Note program station during this interval is on low feedage of 200 lb.

(b) The 10:45-11:30 a.m. drop at the automatic station shows the effect of 9:45 a.m. increased feedage at the program station. Program station is approximately one hour ahead of the plant.

(c) The 11:30 p.m.-12 midnight increased chlorine at the plant shows the effect of the 9:45 p.m. cut-back at the program station.

(d) Period X on chart II, 5 to 5:30 a.m. synchronizes with period X on chart III. The millivolt readings are below 70 and the potentiometer is "laboring" to bring millivolts to 70; chlorine doses increasing in 50 lb. steps each four minutes.

(e) Period Y on chart II, 5:30 to 6:45 a.m. synchronizes with Period Y on chart III. Millivolt readings are above 70 and the potentiometer is "laboring" to bring the millivolts down to 70.

Other points could also be picked off but these notes show the correlation between the program and automatic stations, and also between the potentiometer readings and the automatic rate changes.

Potentiometer Chart

The writer will not comment on this potentiometer chart except to state it is not the straight line he would like. There are considerable hills and valleys, as it were, periods of apparently rather prolonged overchlorination, (so far as the 70 M.V. reading is concerned) ditto under, and one wonders how such a chart signifies satisfactory chlorination.

Let it be noted, however, that just as the proof of the pudding lies in the eating the proof of satisfactory chlorination lies in odor control and our odor control has been both economical and satisfactory, variations in potentiometer reading notwithstanding.

Week-End Holiday and Storm Flows

What has been said in the foregoing applies to normal, week day, dry weather

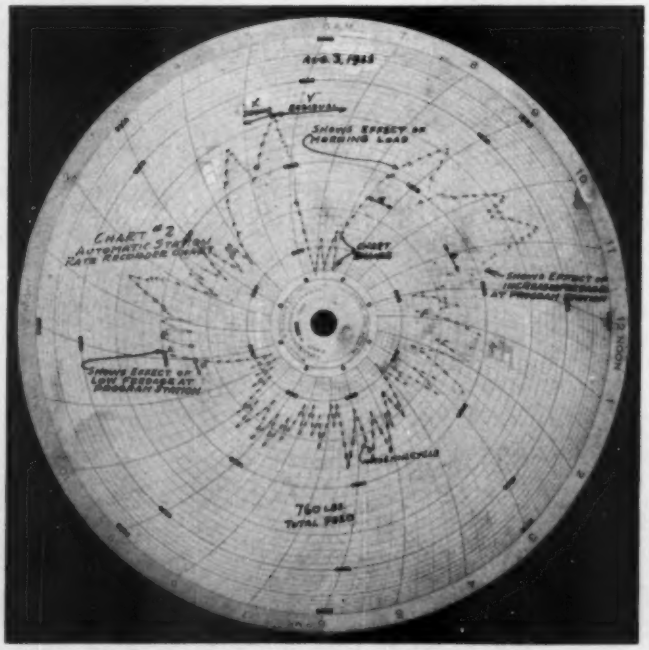


Chart II—Automatic Station Chlorine Dosage Record

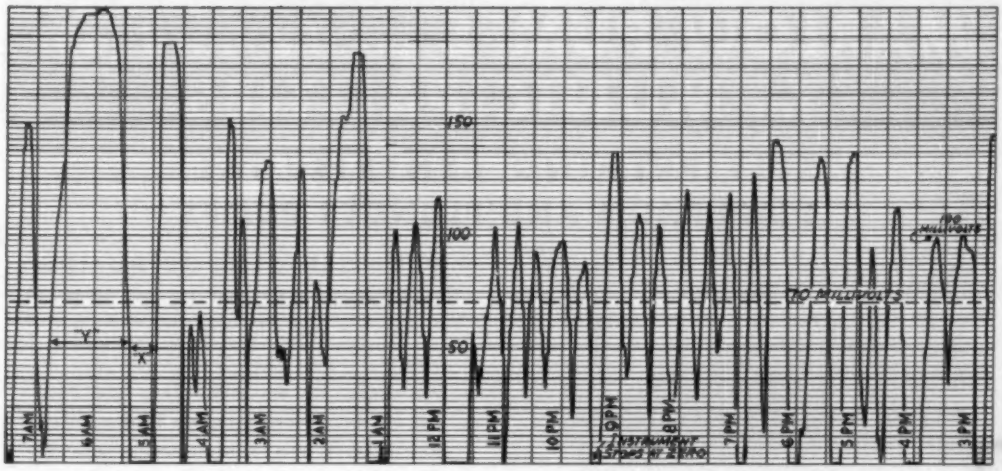


Chart III—Potentiometer Record of Automatic Chlorine Control

operation. It does not apply to week-end, holiday or storm flow periods. For those periods a certain amount of mechanical adjustment is required.

For week-end operation, the procedure is to cut the program station to a minimum feedage of 150 lb. from 5 p.m. Friday to 8 a.m. Monday. This is a simple 30-second job of merely setting the manual control tube for a minimum feedage. When this is done the interval timer keeps right on operating with its periodical changes of vacuum, but irrespective of those changes the machine cannot deliver more than the minimum setting calls for. This is one of the excellent features of this control.

Then Monday 8 a.m., by simply resetting the manual control for maximum feedage the entire unit is brought back on program. This is another 30-second job. A similar arrangement prevails for holidays.

For storm flows of medium duration like a cloud burst with clearing skies or a mere drizzle, the plan is to let the program station run normally but cut off the automatic station entirely. Conditions, of course, alter procedures. Cutting the automatic station is easily acomplished and there is no "travel" inconvenience since the chlorinators are located in the plant proper.

If the storm flow continues unduly, then the program station is also cut back to its 150 lb. minimum. The reason the program station is not completely cut is that when cut completely it takes some little time to re-program and hence cutting manually to minimum chlorine flow is much more practical. Actually the number of times when storm flows have been sufficiently prolonged to necessitate cutting the program station has not been numerous, seldom more than once per summer.

Deleterious Chlorine

One of the questions many activated sludge operators will ask is has the automatic control ever failed to the extent that chlorine sufficient to prove deleterious to the activated sludge was carried into the aeration tank?

The answer to this is that we think so on one occasion but not as a result of failure of the equipment. At the time of the Central Sewage Works Asociation convention in Fort Wayne in October, 1941, during which period the city was deluged with one cloud burst after another, the final effluent at the sewage plant became extremely hazy. Due to our pre-occupation with the convention we didn't catch what was going on until after the meeting was over when we found that throughout those two days the program station had been running full load, resulting in a residual carrying through the primary tanks and into the aeration basins.

Since that time close attention has been paid to the program station during prolonged storm flows, and this plus the potentiometer danger signal as described below has resulted in no further trouble from this source in the intervening 7 years.

Potentiometer Danger Signal

It has been said that during certain storm flows the automatic station is shut down. By this we mean that the transmission of the chlorine call from the potentiometer to the rate controller is stopped and the flow of chlorine from the tanks cut off. The potentiometer, however, is left in operation. This is done to avoid just what happened during the CSSWA convention. During that storm period when the plant chlorinators were cut off the potentiometer was shut down also. The result was that the potentiometer had no chance of indicating the residual which subsequently came along due to the continued high rate of chlorine feedage at the program station. Today our procedure is *never* to cut the potentiometer off during chlorination but keep it going as a warning signal against possible over-chlorination at the program station. As a matter of fact our plant procedures call for hourly readings of the potentiometer by the plant operator, and if a positive reading of 200 millivolts is obtained for two consecutive hours (indicating a slight residual), the chief chemist is contacted and the reason for this is determined.

Average Application

Chlorine requirements are unpredictable: the type summer, hot or cool, and the amount and frequency of rain fall will affect the amount of chlorine needed.

By 1948 we came to the conclusion that chlorination beginning around the third week in June and extending to about the second week in September and requiring three cars of chlorine (90,000 lb.) will be about normal for this plant.

The actual figures for Fort Wayne's eight years of operation, starting and stopping dates, and the average application in pounds per mil. gal. are as follows:

Year	Start	Stop	lb. per mil. gal.
1941	May 23	Nov. 1	83
1942	June 1	Nov. 23	71
1943	June 8	Sept. 28	55
1944	June 15	Sept. 26	83
1945	June 11	Sept. 20	63
1946	June 24	Sept. 17	58
1947	July 1	Sept. 17	57
1948	June 24	Sept. 9	60

Installation Cost

Designing engineers will be interested in the cost of the Fort Wayne automatic chlorine control, about which we have rather complete information. The Fort Wayne Plant costs approximately 1½ million dollars. The cost of the chlorine equipment item by item was as follows, 1939 prices:

Program Station: Chlorinator, $4200; Rate Controller, $1100; Program Timer, $500; and Rate Recorder, $600; Total $6400.

Automatic Station: Chlorinator and Rate Controller $4800; Potential cell and Leeds & Northrup micro-max instrument, $3500; and Rate Recorder, $600; Total $8900; Grand Total $15,300.

Grand total, $15,300 is 1 per cent of the total cost of the plant. Furthermore, the automatic control of $3500 for the potential cell and micro-max instrument is only 23 per cent of the total chlorine installation or ¼ of 1 per cent of total cost of the plant.

Repair Parts

Total out-of-pocket operating cost at Fort Wayne for the six years 1941-46, not including power, salaries, and wages, was $96,014. This includes the cost of all repair parts, pipe, fittings, engine parts, chain, chlorinator parts, fuel oil, gasoline, chlorine, city water, etc. It also includes any maintenance work done by outside crews, city or otherwise. In contrast to this $96,014 figure, the cost of all chlorine equipment repair parts was $442. $442 is 0.46 per cent of $96,014. Whether this is high or low we have no comment. We simply present the figures.

The writer is certain that chief chemist, Paul Brunner, who is directly in charge of chlorination, joins him in this statement: "We have been most thankful for our automatic chlorine control equipment. It has done its job well."

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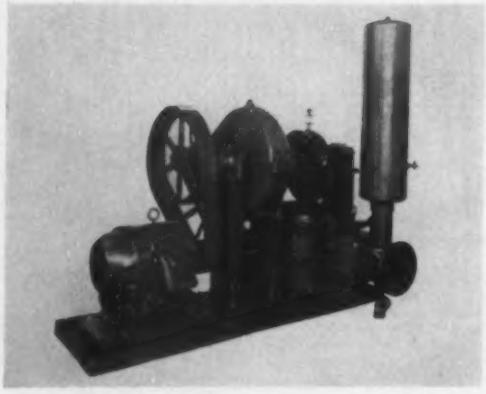

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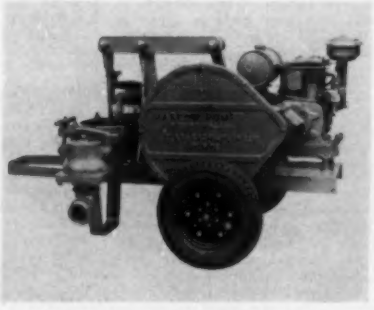

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MANUFACTURERS OF QUALITY PUMPS FOR MORE THAN A QUARTER CENTURY

DIGESTION OF SEWAGE SOLIDS

A Review of Established Methods With Comparison and Comment

By LEROY W. Van KLEECK*
Sanitary Engineer, Hartford, Conn.

PART I
General

THE years just preceding the second world war saw a succession of methods for the digestion of sewage sludge, which, coupled with the older methods of Imhoff and septic tank treatment, might well be scrutinized for their relative worth. The purpose of this discussion is to compare the operating results which have been observed from these various methods.

Available Methods

There are five treatment units available today for the digestion of sludge:

1. Septic tanks.
2. Imhoff tanks.
3. Unheated separate sludge digesters.
4. Heated separate sludge digesters.
5. Lagoons, as supplemental units.

A definition of sludge digestion adopted by the American Society of Civil Engineers and American Public Health Association states:

"Sludge digestion is the biochemical process by which organic matter in the sludge is gasified, liquefied, mineralized, or converted into more stable organic matter."

Practically speaking, operators of sewage treatment plants consider sludge to be digested when its color is dark brown or black, its odor tarry or gassy, its consistency homogenous, and particularly if it can be dewatered on beds of sand in reasonable periods of time without nuisance. So-called digested sludge varies between plants, particularly in the percentage of remaining volatile matter. This latter constituent is dependent on the initial volatile matter content of the raw sludge, the temperature of digestion, the digestion storage period and other factors. It is important therefore to bear in mind that what may be considered as a satisfactorily digested sludge at one plant might not be at another plant.

General Considerations in Method Selection

A careful consideration of the sludge disposal and digestion facilities for a given plant is emphasized by the realization that as much as one-third of the total plant cost may be expended for sludge handling. Furthermore, not only will a mistake or deficiency in the design of these facilities hinder the digestion of the sludge, but it will affect the performance of the treatment plant and the quality of plant effluent.

In selecting a method of sludge digestion, the following general considerations receive the attention of the designer:

1. The proposed location of the treatment plant. This may determine the degree of digestion required to avoid nuisance to nearby houses due to odor travel. It may also, under poor foundation conditions, determine the type of structure to avoid expensive construction for deep units, such as Imhoff tanks.

2. The size of the treatment plant. The population connected or the flow of sewage or both often dictate whether simple or more elaborate sludge digestion facilities are required.

3. The character of the raw sewage. This raises the possibility that stale raw sludge must be handled or that harmful industrial wastes may be present. Such wastes may form scum, or may retard or more seriously interfere with normal digestion processes.

4. The desirability or practicability of utilizing the sludge gas.

5. The size and type of operating personnel to be provided.

6. The funds which will be available for initial construction and for maintenance of the facilities constructed.

*Principal Sanitary Engineer, Conn. State Department of Health.

PART II
Septic Tanks

Except for residential installations, of all the methods for sludge digestion (and sewage sedimentation) none has been more roundly condemned in recent years than the septic tank. To the contrary, the writer believes that not only can such tanks produce effluents comparable with plain sedimentation units, but the sludge deposited in them can be dried and disposed of without serious nuisance, if the plant is reasonably well isolated.

While septic tank plants in Connecticut serving as many as 4000 persons are operating within 200 feet of houses without complaints, large tanks should preferably be removed from houses. If such an isolated plant site is available and the connected population is limited to about 1500 persons, the stage is set for an economical method of primary sewage treatment and sludge disposal. The septic tank has a special field of usefulness for small institutions and factories, in addition to small villages.

Fig. 1—Compactness at Cos Cob, Conn.
Beneath the glass covered sludge drying bed are five septic tanks—note manholes.

Fig. 2. Tank Distributing Inlet
Looking down into distributing manhole serving parallel septic tanks at North Canaan, Conn. Smooth curved section prevents deposits and choking of inlets, proven by long service.

Properly built and operated, septic tanks will give good results. The inherent disadvantage of the septic tank, recognized for many years now, is the difficulty of digesting the sludge and scum in contact with fresh settling sewage without disturbing the sedimentation process. *Tailored design and proper operation* of septic tanks will obviate much of this disadvantage.

Design Requirements

Following are the pertinent design requirements:

1. Build from two to four tanks *in parallel.*

2. Provide bottom sludge drawoffs*, if at all possible, otherwise make provisions for pumping with stationary or portable plunger pumps. Riser-type draw-offs should *not* be used.

3. A *scum* draw-off is an added convenience where the necessary head to the sludge drying beds is available. The scum can be floated into a trough with the aid of the sewage and a hand-skimmer, and discharged directly on to the sludge beds or lagoon.

4. The top of the tank must be fully accessible. If sufficient manholes are provided, these are acceptable, but it is more satisfactory to install large plank hatchways or steel doors of the sidewalk type over the inlet an doutlet sections. Burying of tanks under earth cover should be avoided. Special treatment of wood and protective coating of steel will lengthen the life of the cover.

5. The size of the tanks should be such as to provide a detention of 6 to 8 hours for average daily flows, in addition to an allowance of at least 3.5 cu. ft. per capita for storage of sludge and scum.

6. The tank bottom should either be hop-

*Such draw-offs should pitch continuously and uniformly downward from the tank's lowest point to the sludge drying bed or lagoon.

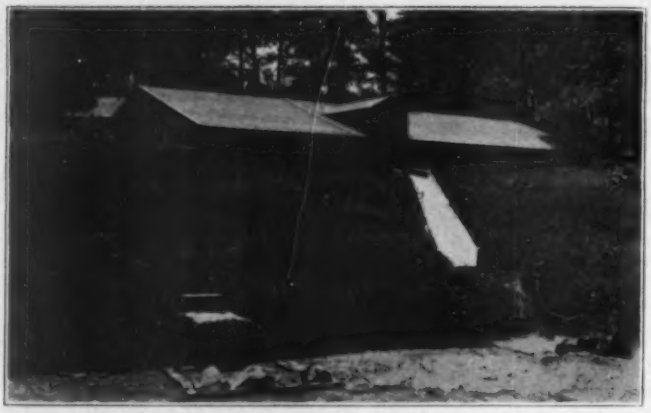


Fig. 3.—Open Top Septic Tank Plant
Housed in and provided with scum trough to sand beds.

pered or it may be flat-bottomed, provided it is sloped to a sump located at either the tank's center or inlet end. Slopes of 1:1 are suggested for hoppers of large tanks where excavation will not prove too difficult or expensive.

7. The minimum water depth of large tanks should be 6 feet. Small tanks should have a minimum water depth of 3 feet.

8. When gravity bottom discharge of the tank contents to a sludge drying bed is not possible (as explained under par. 2) and a pump must be used for cleaning of the tank, both a hand-cleaned coarse bar screen and grit chamber should be considered.

9. If a screen and grit chamber is not required, the flow control manholes for distributing the sewage between the parallel tanks should be designed to maintain self-cleansing velocities, otherwise grit and stones or even rags may be deposited and clog the tank inlets.

10. Tanks should be equipped with outlet baffles; small tanks may have submerged pipe outlets. Good inlet distribution should be arranged.

11. Water or sewage effluent under pressure is highly desirable for sizeable installations as an aid in cleaning the tanks.

Operating Requirements

Following are pertinent operating requirements:

1. One or more tanks are operated in parallel for sewage sedimentation. In colder climates it is desirable to start with clean tanks in the late spring to reduce the intensity of rising septic solids when digestion begins in warm weather.

2. After a period of time, usually 3 to 4 months, but never more than 6 months, the tank or tanks in use should be shut off and their contents allowed to digest undisturbed while other parallel units are in service. In small tanks digestion can be promoted by sprinkling several bags of hydrated lime over the scum and plunging the limed material with wooden plungers. This is done from one to several times during a digestion period extending from 3 to 6 months. In larger installations the tank should be seeded with ripe sludge from a previously digesting unit by means of a recirculating pump. By the process of seeding, a fairly satisfactory sludge is produced, which is admittedly unusual for this type of tank.

In Greenwich, Conn., Doman has carried the process a step further—after seeding he pumps the seeded raw material to a septic tank reserved for sludge and scum digestion. In other words, this septic tank plant is operated as nearly like a separate sludge digestion plant as circumstances permit.

Septic tanks may also be cleaned without advanced digestion of the solids, if the units are isolated from dwellings or if the contents are hauled away for burial or further digestion in lagoons or other treatment units. Drying of semi-raw solids at the plant site, especially of the scum, will be attended by carrying odors, which can be kept at a minimum by drying the material during the cool months of the year and by the use of glass-covered beds or chemical deodorants or both. These aids against nuisance are also effective against fly breeding.

3. When a tank is put back in operation for sewage sedimentation, it should be completely emptied of sludge and scum. If seeding of septic tanks in service is employed, the ensuing digestion interferes with efficient sedimentation. During emptying operations, the relatively clear supernatant liquor between the scum and sludge can be returned at a slow rate to the inlet of the tank or tanks in use without detrimental results to the effluent, thus relieving the sludge beds or saving labor when trucking the scum and sludge away.

4. Following a thorough cleaning, excellent removal of solids and average removal of B.O.D. expected in any form of primary treatment can be expected for several months, provided the tank capacities are adequate. The analyses shown in Table I indicate what may be expected from properly operated septic tanks. All analyses are of samples composited at not more than 15-minute intervals during a daytime sampling period of 6 or more hours.

This sampling represents conditions found with both clean and dirty tanks. The removal of solids compares very favorably with that obtained from the plain settling type of tank.

Conclusions—Part II

Years ago, septic tanks for villages and institutions were built too small, buried under earth, and rarely cleaned, with the result that the effluents were inferior and nuisance resulted. When they were cleaned, such an operation was frequently a major undertaking. Today's design and operation can correct the faults of yesterday and permit an economical design for *limited* connected populations at substantial savings in construction and maintenance.

In respect to the extent of operating attention required, no sewage treatment unit can compete with the septic tank. Turn it on, turn it off, secure partial digestion of the contents if necessary, empty it and start again. Sounds simple—doesn't it? And it is! No matter how many push buttons are provided, a mechanical plant requires daily attention and regular maintenance, not to mention the headaches at small installations due to material scarcities and ever ascending replacement costs.

It has been frequently thought that septic tank effluents are stale or septic to an extent that the efficiency of secondary proc-

TABLE II

Results of Analyses of Septic Tank Influent and Effluent Samples

Plant No.	Population Served	Samples Collected over 8 yr. Periods	Sample of	Av. Susp. Solids, ppm.	Av. Settl. Solids, ml./liter 2 hrs.	Av. B.O.D. ppm.
1	4000	28	Raw sewage	120	4.8	150
		28	Tank effluent	64	0.9	120
2	1800	28	Raw sewage	240	8.8	320
		28	Tank effluent	100	1.2	210
3	175	11	Raw sewage	355	10.0	470
		11	Tank effluent	105	0.2	350
4	750	12	Raw sewage	100	3.0	140
		12	Tank effluent	20	0.2	75
5	1100	19	Raw sewage	210	8.1	270
		19	Tank effluent	57	0.7	140

Fig. 4. A Complete Plant for Small Village
Three septic tanks operated in rotation, sand filters and sludge dewatering beds. These tanks have plank-cover openings and manholes.

esses, such as sand filtration, or contact beds, will be seriously impaired. Careful watch and the analyses of the effluents from sand filters show that this is not true—the over-all removal of solids and B.O.D. being equal and usually superior to all other types of sewage treatment, not to mention the dependability of such units.

It is suggested that we return to a sensible evaluation of the septic tank for locations where its use is indicated, and leave its competitors, the Imhoff tank and the separate sludge digestion plant to their justified applications.

PART III

Imhoff Tanks

When in 1906 Karl Imhoff of Germany introduced the two-story Imhoff or Emscher tank for sewage treatment he made an important contribution to the sewage disposal field. The idea of the two-story tank is said to have originated at the Lawrence Experiment Station of the Massachusetts Department of Public Health in an effort to develop a settling and sludge digestion unit, which would not have the inherent disadvantages of the septic tank. Travis of England also developed such a tank, but he introduced some sewage flow directly into the sludge compartment on the theory that amongst the benefits derived there would be a washing out of excessive enzymes or toxic products of bacterial activity. His idea did not gain favor in America and no Travis tanks, of which the writer has knowledge, were ever built in the United States.

In contrast, hundreds of Imhoff tanks have been and are being built, many of which continue to give very satisfactory results, while others have given operating difficulties and are being replaced with the plain-settling separate-sludge digestion type of plant. At a time when many post-war sewage treatment plants are being designed it is well to consider the reasons for past operating difficulties, under what local conditions Imhoff tanks should still be built, and how past experience can point to the *tailored design and operation* required to produce satisfactory results.

Factors In Adoption of Imhoff Tanks

The choice between Imhoff tanks or some other method of sludge digestion hinges largely on the general factors for the selection of a method of sludge digestion as outlined in the first article of this series, namely: Plant location, connected population and flow, the character of the sewage, the desirability of utilizing sludge gas, the type of operating personnel, and the funds available for construction and maintenance. These factors will now be discussed in order.

Fig. 6.—Modern Imhoff Tank Plant
Serving 14,000 persons this plant is equipped for skimming draw-off through the sludge line or to drying lagoons.

Plant Location

Imhoff tanks should be built on relatively isolated sites at least 500 to 1000 feet from houses. Odors may occur due to disturbance of the scum in the gas vents, skimming operations in the flowing-through compartments, and the escape of sludge gas to the atmosphere.

Connected Population and Flow

Although some large cities are still employing Imhoff tanks, the writer is of the opinion that present day conditions militate against their use for the larger communities. Much of this opinion is based on the manual attention required to properly operate Imhoff tanks, and the difficulties today of securing laborers, even at prevailing high wage scales, to do such labor. Many communities are finding it increasingly difficult to adequately man large batteries of Imhoff tanks. Good workmen are in such demand that they are simply not interested in shoveling, skimming, plunging and squeegeeing non-mechanized sewage tanks. Modern design can still provide, however, a highly satisfactory Imhoff tank lay-out for the smaller community where a suitable site is available.

The writer believes a population from 500 to 15,000 persons would include most cases where Imhoff tanks may well fit into the picture. Large institutions provided with available local help, and towns in a population range from 1500 to 5000 offer special situations for the Imhoff tank as an economical method of sewage treatment and sludge digestion.

Fig. 5. Hand Skimming Operation at an Old Imhoff Tank Plant

Character of the Sewage

Imhoff tanks will handle any given sewage as efficiently as plain-settling tanks unless certain harmful industrial wastes are present. Such wastes might likewise preclude the use of separate-sludge digesters with plain-settling, necessitating the drying and disposal of raw sewage solids. The odor from stale or septic sewage can be controlled by pre-chlorination without affecting sludge digestion in the sludge compartment. In fact pre-chlorination will frequently control foaming of Imhoff tanks as well as prevent carrying odors.

Utilization of Sludge Gas

One of the major benefits of separate-sludge digestion is the utilization of the by-product sludge gas. Plants serving a population range from 1500 to 5000, however, produce insufficient gas to provide more than a small portion of the fuel required for heating in northern climates. Hence, gas utilization for this population range is generally of minor consideration. Septic tanks, while they can be operated to produce good results, present inherent difficulties in this population range. The choice between the Imhoff tank or unheated separate-sludge digester frequently hinges on the type of operating personnel and the funds available for maintenance.

Some Imhoff tanks have been designed to collect gas from the gas vents, but the practice is subject to operating difficulties and has not been extensively employed.

Type of Operating Personnel

The difficulties of securing operating personnel for Imhoff tanks in large cities has already been mentioned. When personnel is obtainable at reasonable wage scales, the total cost for labor will generally be lower than for any other type of primary sewage treatment plant except septic tanks. No mechanical ability is required unless pumping is involved, and a minimum of technical training is needed. Thus unskilled labor can be employed under the supervision of a foreman or chief operator whose qualifications will be largely dependent on the size of the plant. This factor, coupled with the automatic, non-mechanical, and continuous operation of Imhoff tank treatment, is a major argument in favor of the Imhoff tank.

Funds Available for Construction and Operation

While the construction of Imhoff tanks should usually prove cheaper than for separate-sludge digestion type plants, the reverse may be true. As with any type of treatment the cost per million gallons of

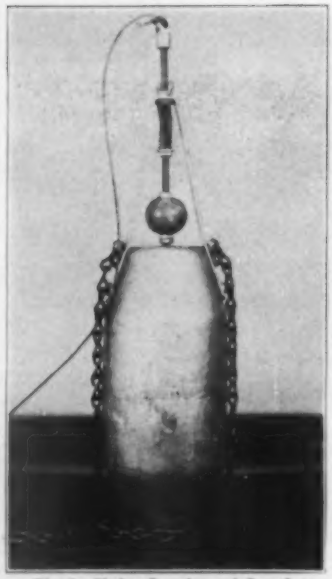


Fig. 7. Sludge Sounder and Sampler
This commercially available sludge sounder has ball stoppers at top and bottom. Submerged to depth desired, a jerk on the cord opens both ports and the sampler fills. The lowering chain is tagged at one foot intervals to determine depth.

sewage treated, or per capita served, will be lower as the size increases. The operating cost of Imhoff tanks, however, for plants of approximately equal connected population should be considerably less than for separate-digestion type plants. Costs of operating plants in the population range of 15,000 to 30,000 in Connecticut average about 38 cents per capita per year. Smaller plant costs may run twice this. Some large cities using Imhoff tanks report yearly operating costs as low as 4 cents per capita. In general, the choice in favor of Imhoff tanks versus another type of plant will not generally be greatly influenced by the funds available for construction, but if low maintenance costs are desired and the other influencing factors are favorable to Imhoff tanks, this type of plant will prove most economical, the per capita cost being frequently one-quarter to one-half that for separate-sludge digestion.

Design Requirements

Following are pertinent design requirements. The items listed do not include all of the factors which enter into the design of Imhoff tanks but they do represent those considerations which the writer's experience have shown to be particularly important.

1. The *minimum sludge storage capacity*, from hopper bottom to 18 inches below the slots, for tanks in northern climates should be *at least 3.5 cu. ft. per capita* served, and preferably 4 to 5 cu. ft. Experience indicates that most of the operating difficulties with foaming excessive scum accumulations, solids rising through the slot pronouncedly, odors and poor sludge quality would not have been experienced had the tank storage space for sludge been more liberal than originally considered sufficient. If the Imhoff tank is to receive secondary tank humus sludge, the above sludge capacities should be at least 5 to 6 cu. ft. per capita and preferably more. The digestion of activated sludge in Imhoff tanks along with crude solids is not considered practicable and cannot be recommended.

2. The *flowing-through chamber capacity* should provide a detention of *not less than 2½ hours* for the average dry weather flow. Surface area loadings should, furthermore, not exceed *1000 gal. per sq. ft.* (preferably 800) of flow-chamber surface for the 24-hr. average dry weather flow. With reasonable operating attention these design factors will afford a removal of suspended solids equal to that obtained with plain-settling type tanks. Table II gives the analytical results of the examination of Imhoff tank influent and effluent samples collected at a number of plants over a period of 8 years.

3. *Pre-treatment of sewage prior to Imhoff tank settling* should include screening through *1-inch to 1¼-inch clear-opening bar screens followed by a grit chamber.* The 1-inch screens for the larger plants should be mechanically cleaned. The 1½ inch screens for the small plants may be hand cleaned. Generally two or more narrow hand-cleaned grit chambers will suffice for the smaller plants. Grit chambers should be provided regardless of the plant's size or whether the collecting sewers are combined or separate. These units are inexpensive and have almost without exception proved their worth at one or another time.

Many Imhoff tanks fail to operate properly because of accumulations of rags, paper and other fibrous materials in the gas vents, and grit in the sludge compartments. Modern design can correct these former faults by giving the Imhoff tank the same break we have given the plain-settling tank. The writer favors screening of sewage for Imhoff tanks with actual removal of the screenings, rather than disintegration of screenings with their return to the sewage flow. Removal of the screenings reduces the tendency for formation of coarse slow-digesting solids in the gas vents which contribute to scum matting and choking of these channels of gas escape.

4. The *fewer the hoppers and dividing walls in the sludge compartments, the better.* Restrictions in the lower compartment of Imhoff tanks tend to segregate sludge deposits, interfere with effective seeding of the raw solids, result in "lime pockets" when lime is added to the digestion compartment, correct acidity, increase the cost for sludge piping and valves, and necessitate more frequent reversal of sewage flow through the tank. Tanks with flat-bottoms and those with continuous or single hoppers have worked very successfully without any flow reversal. Where cross-walls are required for structural strength they should be built astride the flow-chamber sides just above the slots but not higher than 3 ft. below the tank flow-line. This will give unobstructed gas vent surfaces for the scum removal lay-out suggested later.

TABLE II

Results of Analyses of Imhoff Tank Influent and Effluent Samples

Plant No.	Population Served	Samples Collected Over 8 Yr. Period	Sample of	Av. Susp. Solids, ppm.	Av. Settl. Solids ml./liter, 2 hrs.	Av. B.O.D. ppm.
1	500	23	Raw sewage	200	5.7	370
		23	Tank effluent	90	0.3	250
2	1,850	15	Raw sewage	200	7.2	180
		15	Tank effluent	40	0.4	47
3	10,500	26	Raw sewage	115	5.0	100
		26	Tank effluent	45	0.5	60
4	500	13	Raw sewage	185	6.0	205
		13	Tank effluent	80	0.2	175
5	13,000	26	Raw sewage	200	5.5	105
		26	Tank effluent	90	0.8	80
6*	36,000	33	Raw sewage	215	7.0	250
		30	Tank effluent	115	1.0	195

*Overloaded plant now replaced with plain-settling tanks.

Fig. 8. Small Plain-Settling Unheated Separate Sludge Digestion Type Plant, North Manchester, Conn.
(Digester is on hill with operating gallery showing. Settling tanks have sludge scrapers.)

5. *Imhoff tank slots* should be baffled by adaptation of the scheme of the overlapping concrete apron.. Triangular beams used between the converging aprons of the sloping walls are unsatisfactory and serve to accumulate a variety of hanging of stringy materials and coarse solids. These beams also serve as a foot-hold for biological growths. In contrast, an overlapping apron is more or less self-cleansing and is far simpler to keep free of deposits and biological growths through use of the squeegee from one side of the tank.

6. In addition to *minimum slope of 1¼ vertical to 1 horizontal* for the sloping walls of the flow chambers, the use of carefully smoothed concrete for the aprons is highly desirable. The smoother the concrete, the better and easier will be the squeegeeing job. Sludge compartment inspection manholes in the aprons should not be built. They are rarely level with the aprons and may become dislodged.

7. The same care should be given *Imhoff tank inlet and outlet design* as is given the plain settling type of tank. Poor distribution of flow to tanks, clogging of narrow inlet gates, and lack of sufficient effluent weir length are common faults in the older tanks. The use of narrow gate outlets or submerged pipe outlets should particularly be avoided in favor of full-width weir overflows.

8. *Deep tanks function better* than shallow tanks because of greater sludge storage depths. They afford better opportunities of withdrawing sufficient quantities of ripe sludge without drawing off too much seed material or partially-digested solids. Experience indicates that in general tanks 25 to 30 feet deep will produce better sludge, have less scum and give rise to less foaming difficulties than tanks 20 to 25 feet deep. Tanks less than 20 feet deep are usually unsuccessful in operation.

9. All *valves* should be located outside of the tank for accessibility and again to provide unobstructed gas vent areas.

10. All *walkways* for squeegeeing and skimming operations should have a minimum width of 15 inches. This width will permit reasonably safe tank maintenance without the need of supplemental wooden planks which eventually rot or may become dislodged.

11. In those rare cases where sufficient head is available, a *bottom sludge draw-off*, pitched continuously and uniformly downward from the tank's bottom to the sludge drying bed or lagoon, is highly *desirable*. Such a draw-off will keep accumulations of lime, foreign objects and grit moving out with the bottom sludge. The *second-best* arrangement is a *riser type* draw-off with the horizontal take-off several feet below the flow-chamber slots. This will permit drawing down of the tank level for flow-chamber and slot inspection, a highly desirable arrangement. If a *supernatant liquor draw-off* to a similar depth is installed this will offer the same advantage, and without loss of the seeded digested sludge from the bottom. The increased cost for a supernatant draw-off connection is not great. The initial available head on the sludge outlet line should never be less than 5 feet. Sludge lines should have a minimum size of 8 inches.

12. An all too frequent major operating difficulty with Imhoff tanks is the *scum accumulations in gas vents*, primarily because no facilities have been provided for scum removal except by the time-worn wheelbarrow parade. While gas vent scum draw-offs through pipes or sliding gates are far from new, it is surprising how few Imhoff tanks have been equipped with them. The gas vent area should be unobstructed, and one or more bell-shaped flanges attached to 8-inch or larger pipes should be set in the vents at an elevation 6 inches under the normal flow line. The pipes should be valved outside the tank and connected into the sludge draw-off line discharging to the sludge drying beds or a lagoon. A depth of 6 inches is about right; less depth hinders scum removal and frequently causes scum clogging of the piping, while greater depths withdraw too much subnatant liquor. Sliding gates installed on the outside walls at each end of the gas vents have been used at some plants and should prove satisfactory substitutes for pipe flanges.

13. Hand-skimming of Imhoff tank flow-chambers should not be necessary in this day and age. In many plant lay-outs the prevailing wind will concentrate surface skimmings at the removal end of the chambers. A floating scum board, the width of the chamber, can be dragged from one end to the other, or a water spray with a hand hose or permanent water pipe nozzles can be used to drive and concentrate the scum. A slotted swivel pipe can then be used to remove the skimmings by gravity to a concentration well or directly to a special drying bed. Such draw-offs are commonly used for rectangular plain-settling type tanks. One or more draw-off pipes fitted with bell flanges and pipe valves just under the tank surface may also be used as a substitute. Such draw-offs and valves help to reduce much of the time consuming labor required for hand skimming and are well worth the small additional cost.

Operating Requirements

The following requirements are not intended as a complete guide for plant operation, but in the writer's opinion will help to avoid some major operating difficulties. Most operators will agree that operating troubles center around foaming, scum accumulations, carrying odors, and rising sludge in the flowing-through chambers. Poor sludge quality plagues some badly overloaded plants.

Fig. 10. Same Digester as in Fig. 9 (Showing walkways and safety railings. Note broken up condition of scum which is about one foot thick and ready for drawing to sludge beds.)

Foaming

When frothy material rises in the gas vents above the normal water surface, this is called mild foaming. Real foaming results in the overflowing of froth from the gas vents into the flow-chambers and onto the surrounding ground. A general mess is the result. The writer is grateful that he has not had to cope with a real case of foaming for many years.

Foaming is invariably associated with overloaded plants or new tanks started without seeding in cold weather. In northern climates spring may bring the foam, attributed to be largely soapy materials which rise with the vigorous gas production accompanying accelerated spring activity in accumulated dormant winter sludge.

Deep tanks with adequate storage will foam less than shallow tanks with their limited sludge storage. Foaming may occur regardless of whether alkaline or acid conditions prevail in the digestion compartment liquor and sludge. If an acid condition is present (indicated by a total alkalinity below 1000 ppm. or a pH below 6.6), moderate amounts of lime will sometimes stop foaming.* Excessive hosing of the gas vents actually aggravates foaming, interferes with sedimentation and increases the chlorine demand of the tank effluent. The hydraulic head produced in the digestion compartment as the result of hosing the vents seeks a level through the slots, resulting in displacement of supernatant liquor and frequently of solids into the flowing-through chambers.

The best cures for foaming are:

1. Rest the tank if possible.
2. If all tanks must be kept in operation, draw some sludge, leaving in plenty of seed sludge.
3. With overloaded tanks, maintain alkaline conditions by small *periodic* additions of milk of lime or dry hydrated lime to the gas vents, working the lime into the scum with a paddle or other manually operated agitator. Avoid dumping large quantities of lime into the vents at one time. This will cause lumping and building up of lime pock-

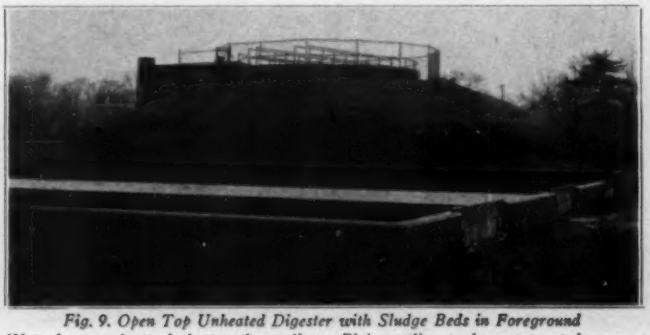


Fig. 9. Open Top Unheated Digester with Sludge Beds in Foreground (Note fence and attached operating gallery. Plain settling tanks and pump house not visible.)

*Suggested quantities of hydrated lime may vary from 15 to 80 lb. daily per mil. gal. of sewage treated, or 2 to 10 lb. daily per thousand persons connected.

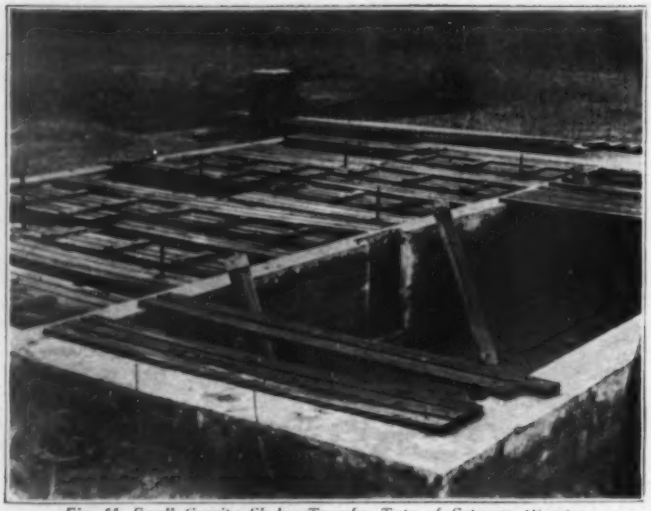


Fig. 11. Small Gravity Sludge Transfer Type of Separate Digester
(Settling tank in foreground, separate digester to left. Note sludge riser pipes, scum draw-off port between settling tank and digester and sludge beds in distance.)

ets under the slots with eventual difficulties with sludge digestion and scum formation.

Scum Accumulations

Excessive scum accumulation in gas vents is abnormal and indicates either an overloaded plant or lack of operating attention. The writer believes in giving gas vents attention. Scum should be lightly hosed, paddled, limed and otherwise encouraged to settle when weather conditions permit. Holes should be maintained through the scum for gas release. Several times a year rags and other coarse materials in the gas vents should be forked out. Slow digesting or non-digestible material like match sticks and hair should be scooped out of gas vents at least once a year. When a draw-off for the scum is available this, of course, is used instead of the hand scooping.

If valved pipe draw-offs have been installed in the flowing-through chambers for skimmings removal, one method of removing scum from the gas vents is to draw down the tank as near to the slots as possible. Much scum will rise through the slots and accumulate in the flowing-through chambers, whence it can then be floated into the draw-off pipes.

If after a period of years, grit, lime and other heavy solids accumulate in the sludge compartments, normal seeding and digestion will be seriously affected with the likelihood of excessive and persistent scum build-up in the gas vents. Although a major job is frequently in prospect, the tank in such cases may need to be dewatered and completely cleaned. In some cases an ejector lowered to the hopper bottoms can be employed to scavenger the grit and silt laden hoppers. When good water pressure is available, or a portable pump is employed to provide effluent under pressure, a crude ejector can be constructed of pieces of pipe and pipe fittings if a suitable ejector cannot be procured.

Odors

Cleanliness is good insurance against odors. Pre-chlorination (mentioned earlier) will markedly reduce odors from septic sewage. By intelligent operation even very local odors from Imhoff tanks can usually be kept below the nuisance stage.

Rising Sludge

The floating of partially-digested or digested sewage solids in the flowing-through chambers of Imhoff tanks is generally the result of:

1. Sludge depths higher than 18 inches from the slots, generally at or above the slots.
2. Scum depths extending downward to the slot level, so that solids break off from the bottom scum layer and rise through the slot into the flow chamber.
3. Dirty aprons or clogged slots.
4. Excessive hosing of scum.
5. Structural defects in the slot. (Wrong construction, insufficient overlap, broken edges, etc.)
6. Seasonal over-turns caused by temperature changes within the tank.

The remedies for these conditions are either self-evident or have been previously discussed.

Sludge Quality

Sludge quality is mostly dependent on plant capacity; secondly on the method of operation. Draw sludge slowly, in small quantities and frequently! In late fall in cold climates, draw sludge until winter storage requirements are secured. Hold off

TABLE III
Analyses of Imhoff Tank Sludges

Sample No.	% Moisture	% Fixed Solids Dry Basis	% Volatile Solids, Dry Basis	Total Alkalinity, ppm.
1	94	57	43	1300
2	92	51	49	1200
3	94	48	52	1900
4	93	63	37	1100
5	90	49	51	1400
6	80	54	46	2900
7	92	55	45	1700

Fig. 12—Modern Heated Separate Sludge Digestion Plant.
Boasts a record of no complaints from closely located residences during 16 years of operation.

Fig. 14—Waste Digester Gas Burner.

A standard appurtenance at heated digestion tank plants, burns surplus digester gas to preclude odor complaints and explosion hazards.

spring drawing in the north as long as possible. Infrequent drawing of large amounts of sludge is not good practice under any conditions and may lead to much trouble. Table III gives some analyses of Imhoff tank sludges from tanks of adequate capacity. Such sludge is a pleasure to behold, being almost jet black in color, strongly tarry in odor, freely dewatering, and of good weight. The most modern of separate-sludge digesters frequently fail to produce any better product.

Tools

A word about tools. Frequent use should be made of a reliable sludge sounder, such as that pictured in the accompanying cut. Pitcher pumps are awkward and messy in operation by comparison. Weighted ball-floats or metal discs are not accurate for sludge soundings.

Other tools should include several squeegees with short and long handles (one for the vertical walls and one for the sloping walls and slots), round or square scum plungers (churners) of metal or wood, a scum pusher, if you are blessed with scum draw-offs, a hand skimmer of ¼-inch wire screening or fish netting, if a mechanical skimmer is not available), and a chain slot-cleaner. Squeegeeing of the flow-chamber aprons and cleaning of the slots should generally be a weekly chore.

The tools for Imhoff tanks illustrated in most current books and releases are too heavy and of awkward size. The energy expended in manipulating these tools is too great. Squeegees should be 24 inches wide, and the belting or rubber extended not more than 1¼ inches beyond the holding frame. Skimmers should be 6 inches deep, but not over about 10 x 18 inches in plan. For a drag chain, use one about 3 feet long (not 6 feet) and weighing around 5 lbs. Twisted link chain of 7/16 inch stock is about right.

Conclusions

Imhoff tanks of proper capacity and depth, and with good operation, will function satisfactorily. Given a fairly isolated location they may economically serve communities and institutions in the population range from 500 to 15,000, in particular from 1500 to 5000. Unskilled labor can be used, and per capita operating costs are low.

Such plants should be provided with pretreatment units providing screening and grit removal, and equipped with mechanical aids for withdrawing gas vent scum and flow-chamber skimmings.

PART IV

Unheated Sludge Digesters

The 1938 "Committee on Sludge Digestion" of the American Society of Civil Engineers states that there is doubt as to the first use of the method known as separate digestion. In 1884, however, separate digestion tanks were used in tests at London, England, and again at the Lawrence Experimental Station of the Massachusetts Department of Public Health in 1899. While Imhoff tanks led the field in this country during 1910 to 1920, the trend since 1920 has been toward the adoption of the separate system of sludge digestion.

Factors in the Selection of Unheated Digesters

While the general factors previously discussed for the septic tank and Imhoff tank must be considered, the decision to use unheated separate digesters also involves the variety of uses under which they may be employed. These are as:

1. Rectangular or possibly circular units with gravity transfer of raw sludge from adjacent hopper-bottom plain-settling tanks.
2. Elevated open-top units, usually circular, to which raw sludge is pumped from either hopper-bottomed settling tanks or tanks equipped with conventional scraper mechanisms.
3. Circular open-top units used as secondary units following primary digestion of raw solids (two-stage digestion).
4. Circular and sometimes rectangular covered units, also used as secondary units following primary digestion of raw solids. Such units may have fixed covers, floating covers, or a gas-storage holder which rises and falls with the gas volume in storage. In most cases the sludge gas is collected and utilized.

Methods No. 3 and No. 4 are so closely tied in with heated separate sludge digesters that the factors influencing their use, together with their design and operation, will be discussed in Part V of this series.

Plant Location

A site suitable for a septic tank or Imhoff tank plant will be suitable for unheated digesters. Because of the advantage of separate control of the sewage settling and digestion processes, carrying odors from this type of plant should be under better control than with Imhoff tanks.

Connected Population

The unheated digester is a competitor of the Imhoff tank in the 1500 to 5000 connected population range. Below 1500 population the writer favors the septic tank for reasons discussed in Part II. Between 1500 and 5000 population, unheated digesters have their field of greatest usefulness. The cost of operation and maintenance is low, although generally not as low as for Imhoff tanks handling the same population. As the connected population increases above 5000, a point is reached, when gas utilization in heated digesters becomes a factor. Such heating reduces materially the volume of digestion space required and while the gas production in winter may not be sufficient to supply all heat requirements of the digesters and operating building, it will be sufficient, coupled with standby fuel, to warrant the shift.

Character of the Sewage

With proper design and operation, the efficiency of sewage sedimentation is as-

(*Continued on page* R-154)

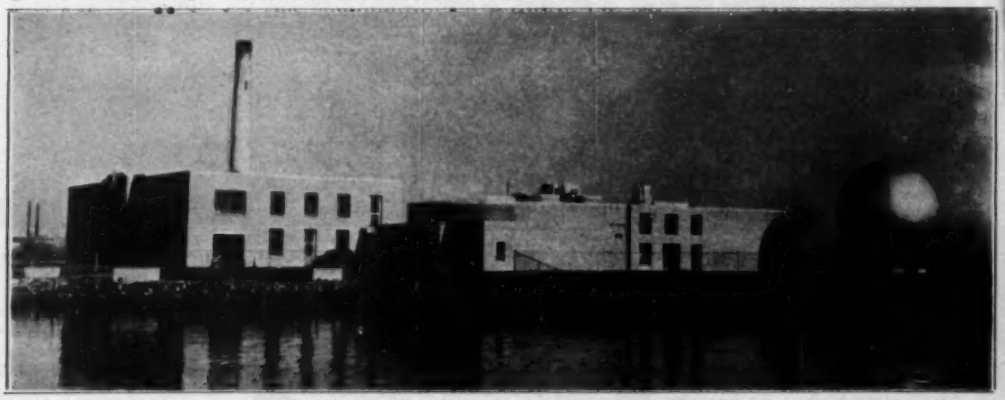


Fig. 15—New Haven's Modern Separate Digestion Plant.
Note pressure gas-storage Hortonsphere on right—sometimes referred to as the "bubble of progress" in sewage treatment.

LINK-BELT SANITARY ENGINEERING EQUIPMENT

for

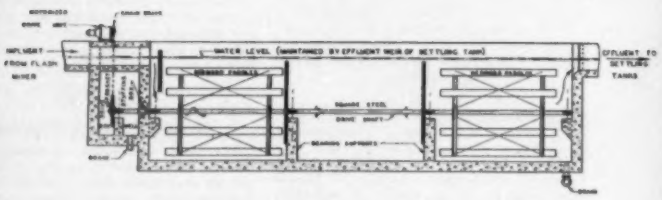
SOLVING WATER, SEWAGE AND INDUSTRIAL LIQUIDS TREATMENT PROBLEMS ... ENGINEERED AND

STRAIGHTLINE BAR SCREENS

—for removal of floating solids over ½" in size, from incoming sewage or industrial liquids, thus assuring an even flow through the channel. Send for Folder No. 1587.

TRITOR SCREENS

—are used for the removal of screenings and grit at small sewage treatment plants. With the Tritor Screen, one mechanism accomplishes removal of both grit and screenings. Send for Book No. 1587.



HORIZONTAL SLOW MIXERS

—for rectangular tanks where horizontal flow is desired. The degree of mixing can be reduced as the water flows through the tank by decreasing the number and changing the pitch of the paddles. Send for Folder No. 2042.

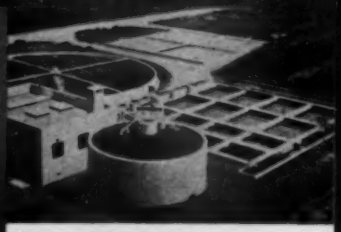
ALL FROM ONE SOURCE . . . ONE RESPONSIBILITY . . .

STRAIGHTLINE SLUDGE COLLECTORS

—for rectangular settling tanks, Straightline Collectors with peak-cap bearings, pivoted flights and "Straightline" action provide a combination which can't be beat for efficient collection of sludge and grease. Send for Book No. 1742.

CIRCULINE SLUDGE COLLECTORS

—for round settling tanks. Circuline collectors are equipped with "Straightline" action which assures quick and positive sludge removal from the entire tank floor in one revolution. Send for Book No. 1982.



BIO-FILTRATION SYSTEMS

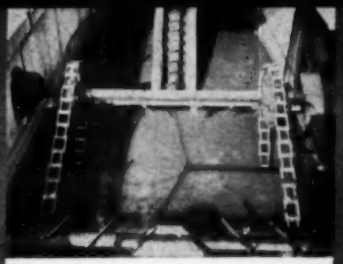
This system consists of high rate shallow filters and recirculation of the effluent from the filter to the settling tanks. Features are: great flexibility, high rate of B.O.D. loading and the ability of plants to handle strong domestic and industrial sewage in single-stage or two-stage treatment, as required. Send for Folder No. 1881.

THRU-CLEAN BAR SCREENS

—a coarse bar rack and chain operated rakes equipped with fingers that clean through the rack from the back. The screen cannot be jammed by large objects since the rake will enter under and lift them. Send for Folder No. 2327.

LIQUID VIBRATING SCREENS

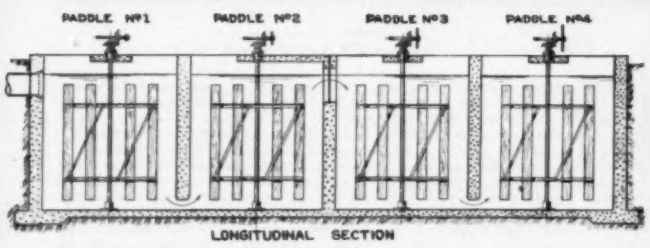
—an efficient and economical screen for the removal of solids from industrial liquids. Units are available in several sizes with coarse or fine screen medium. Send for Book No. 1977-A.



STRAIGHTLINE GRIT COLLECTORS

—for the removal of a clean, washed grit with a low putrescible content, the collecting and thorough cleaning operation with Link-Belt grit washer makes further handling unnecessary. Send for Book No. 1942.

COORDINATED FOR MOST EFFICIENT PERFORMANCE...



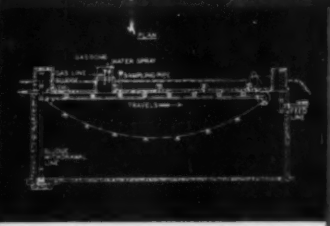
VERTICAL SLOW MIXERS

—for square tanks which can be constructed singly or in a series of two, three or four. These mixers will provide efficient mixing and flocculation where vertical flow is desired. The mixers can be operated at a decreasing rate of speed to produce the maximum size floc. Send for Folder No. 2042.

FLASH MIXERS

—for rapid and thorough mixing of chemicals with water, sewage or industrial liquids. A large, efficient four-blade propeller operates with or without under water bearing. Send for Folder No. 2042.

ONE HIGH STANDARD OF QUALITY...



STRAIGHTLINE SCUM BREAKERS

—are used in either round or rectangular digestion tanks to break up the floating scum, paddle it down and submerge it. The scum breaker consists of two stands of chain with pitched flights between them, traveling at a slow speed. Send for information.

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(*Continued from page* R-151)

sured by the plain-settling, separate-sludge digestion type of plant. As with Imhoff tanks, however, harmful industrial wastes, such as copper, chromium or wool fibre, in toxic or excessive quantities, must not be present or digestion will be unsatisfactory and nuisance develop. Designers of modern sewage treatment plants have a responsibility to their clients to ascertain that no such wastes are present in the sewage or to take steps to pre-treat or exclude them.

Operating Personnel and Cost of Operation

The performance of septic tanks and Imhoff tanks is not likely to be so adversely affected by deficiencies in operating personnel as is the separate digestion system. This, coupled with lower operating costs, is why the author has favored the septic tank and Imhoff tank for the small community, institution, or factory.

Operators of unheated digester type plants must frequently have mechanical ability, be able to perform simple laboratory tests, keep records, and give routine attention to the plant. With these qualifications they generally command a higher salary than operators of septic or Imhoff tanks handling the same population.

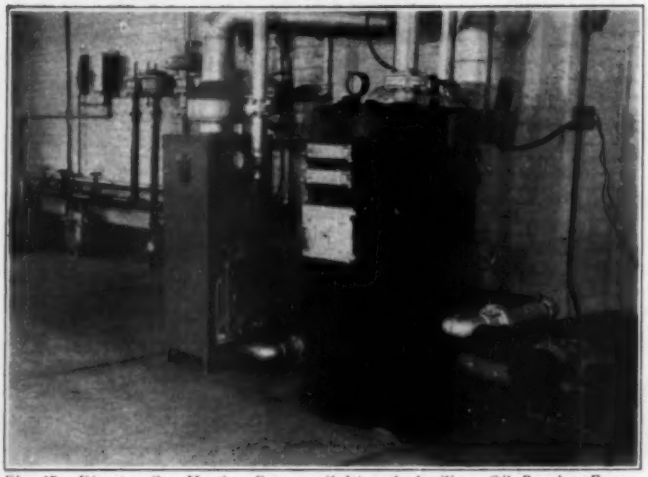

Fig. 17.—Digester Gas Heating Furnace (left) and Auxiliary Oil Burning Furnace (right) at Putnam, Conn.
These units can be operated singly, in parallel or in series.

Pertinent Design Requirements

1. Provision should be made for screening and removal of grit from the sewage flow. This requirement should apply to all sewage treatment installations of any size except some septic tanks (see Part II). Grit chambers are needed whether or not the collecting system is on the separate plan. Two or more narrow hand-cleaned grit chambers should prove satisfactory. Hand-cleaned screens should give way to mechanical screens or disintegrators for connected populations above 5000.

2. The minimum sludge storage capacity should be 3.5 cu. ft. per capita and preferably 4 to 5 cu. ft. With the addition of humus sludge the minimum allowance should be 4.5 cu. ft. per capita. The addition of waste activated sludge to such tanks cannot be recommended.

3. The valves on gravity sludge transfer pipes between adjacent plain-settling and unheated separate digesters should be protected from freezing. This is a frequent operating headache in northern climates. Submerge of the valves in sewage will generally prevent trouble.

4. With gravity sludge transfer pipes, the digester discharge should be visible at maximum liquid elevation in the digester. This enables an operator to see the character of the raw sludge being drawn. A 90 degree fitting with extension piece can be used if required. Minimum withdrawal head for sludge transfer should be four to five feet.

5. The digester top should be fully accessible for scum plunging. Treated plank covers are suitable for rectangular units fed by gravity sludge lines. Eventually, of course, such covers rot. Covers improve the appearance, reduce carrying odors, and keep out ice and snow. Sections of the cover can be left in place, when working on the tanks.

With larger circular tanks, elevated above ground level, and to which raw sludge is pumped, covers are not necessary, since normal gas odors are readily dissipated into the air, the top surface is not visible to a ground observer and in northern climates the scum can be left undisturbed until the ice and snow melt in the spring. Open top tanks require, however, a concrete walkway or wide heavy planking (minimum width two feet) for scum plunging operations, and should furthermore be surrounded by a high substantial fence to prevent accidents to trespassers, not to mention the protection it affords the digester from foreign objects being thrown into it.

6. Scum and sludge levels in small rectangular digesters can be determined with a type of sludge sounder described under Imhoff tanks. Large circular digesters to which raw sludge is pumped should preferably be designed with an operating gallery accessible at grade in which is located the supernatant and sludge draw-off piping, control valves, and a sampling sink. The sink should be at least 18 inches deep, have a 3-inch drain, and be supplied with 1¼ or 1½ inch sampling pipes with quick opening valves from the various digester levels. A water supply not cross connected with a potable water supply should be piped to the gallery for back-flushing clogged lines and rinsing the sink. The gallery should be heated. If the operating building is built adjacent to the tank, a portion of this building can be utilized as a pipe and sampling gallery, thus saving the cost of a separate gallery.

7. Rectangular digesters adjacent to settling units should have a minimum water depth of 8 ft., preferably 10 ft. Circular tanks for larger plants, to which sludge is pumped, should be at least 20 ft. in depth and are frequently deeper.

8. Decanting pipes at 2 to 3 ft. intervals should be provided throughout the normal zone for scum and supernatant liquor storage. The liquid level of rectangular digesters adjacent to settling units is of necessity below that of the settling units. Supernatant liquor is best handled at these small plants by drawing it on to one or two sludge

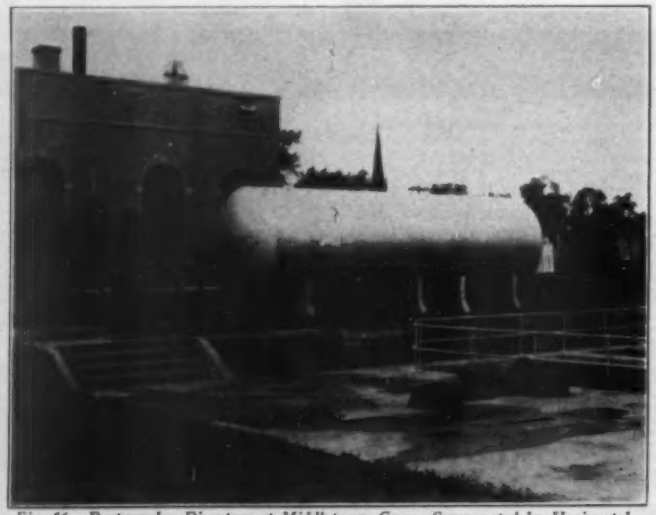

Fig. 16.—Rectangular Digesters at Middletown, Conn., Surmounted by Horizontal Pressure Gas-Storage Tank.

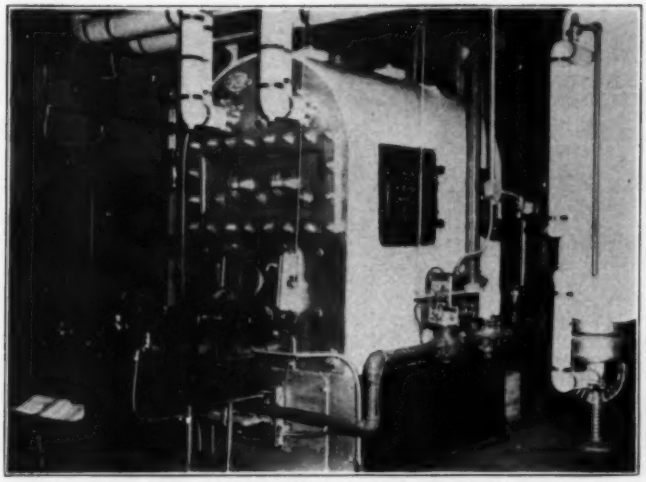

Fig. 18.—Hot Water Boiler at Torrington, Conn.
Operates ordinarily on digester gas but is equipped for oil burning, if and when necessary.

beds reserved for this purpose. Pumping of the supernatant to the raw sewage not only requires additional equipment but the low flow at such plants affords insufficient dilution for the liquor. A means for discharging skimmings from the settling tanks to the digester is convenient. A handy arrangement is illustrated in Fig. 11.

Supernatant from elevated circular digesters can be returned at a slow rate to the raw sewage flow, but an alternate arrangement for draining on sludge beds is desirable. Slow rates of return can be secured by utilizing the small sampling sink pipes instead of the larger decanting pipes. At least two of the supernatant liquor draw-offs should be of 8-inch pipe, one located about a foot below maximum high water and the other about 3 feet lower. *These pipes can then be used to draw off partially digested liquid scum, which has been previously broken up, to the sludge beds.*

Pertinent Operating Features

1. Open unheated digesters present no explosion hazard and very little fire hazard. This safety feature, coupled with the omission of gas-fired boilers, meters, flame traps, pressure regulators and condensate traps, simplifies operation. Less knowledge and mechanical aptitude are thus required of the operator than with heated digesters.

2. These units should preferably be started in the north during early spring or summer. The exact procedure will be discussed in detail under Part V on "Heated Digesters."

3. Seed sludge must be kept in these units as with Imhoff tanks. The sludge level should be drawn down in the fall in the north to provide storage during the winter when very little digestion will occur. At best, tank temperatures will not exceed that of the raw sewage, and will fall lower in exposed locations. It is always wise to have several clean sludge beds ready to receive sludge in winter in case some sludge must be drawn. When sludge of suitable drying quality is obtainable during favorable drying weather it should be drawn in *limited* amounts *frequently*.

4. Raw sludge through gravity lines should be drawn *slowly* to the digester until water streaks are visible. Samples of the sludge should be observed at close range, if necessary, to cut down on the overflow liquor volume. The sludge in plain-settling tank hoppers should be squeegeed down the sides of the hoppers; otherwise, the sludge will not be effectively removed and a build-up of solids on the sides of the hoppers will occur with subsequent rising of sludge masses, especially during warm weather. After sludge has been drawn from all hoppers, a second short drawing is often beneficial. With mechanically-cleaned settling tanks, sludge removal follows the usual pattern.

5. Supernatant should be drawn from the level shown by sampling to contain the lowest solids content. A simple test for small plants with limited laboratory equipment is to settle a sample of the supernatant in a graduated cylinder for one hour. Solid accumulations under 5 per cent by volume indicate a good liquor; readings to 10 per cent can generally be returned to the raw sewage flow without operating difficulties, especially if returned at a slow rate or if the sewage flow is sufficient to provide good dilution. Liquor containing more than 10 per cent solids by volume should be sent to sludge beds or retained if possible. Supernatant liquor is generally drawn once or twice a week to make room for the addition of fresh sewage solids. Automatic overflow of supernatant during raw sludge additions is generally neither necessary nor desirable.

6. Scum floating on the digester surface should be worked with a light wooden plunger or similar tool, or occasionally, if required, broken up with water, sewage, or supernatant liquor under pressure. The use of supernatant is preferable. When a foot or more of semi-liquid scum has accumulated it can be drawn off through the supernatant pipes recommended under design requirements. This will rid the tank of floating hair, match sticks, rags, and other slow digesting material. By promotion of scum digestion through routine submergence of it, the material will be black and have no appreciably greater odor than bottom sludge. The drying time on the sludge beds will usually be longer than for bottom sludge drawn to the same depth, because of the character of the material.

Lime in judicious quantities will often aid in settling scum and promoting better digestion. Its use is by no means always necessary, nor should it be used unless a real need is evident. The pH of the sludge may be allowed to drop to 6.4 or 6.5 before adding lime. In the interim every effort should be made to promote digestion by submerging scum, maintaining plenty of seed sludge, adding raw sludge in proper quantities at regular intervals and recirculating the tank's contents if the pH or total alkalinity values are widely different in various zones of the tank. While the writer does not subscribe to the theory of artificial maintenance of high pH values with lime, he does believe that lime has a definite use in sludge digestion. This matter will be discussed in detail in Part V.

7. Odors from these tanks, when properly operated and not subjected to overload, are not offensive and are generally confined to the immediate vicinity of the tank. Frequently no odor can be detected at the base of elevated open-top tanks.

8. Table IV gives the results of some analyses of digested sludge from unheated separate-sludge digesters in Connecticut. It will be observed that most of the results compare favorably with what is considered well-digested material. In some cases the high alkalinities and fixed solids reported are partially the result of lime additions, admittedly excessive in some instances. Other tanks have been operated with little or no lime.

Conclusion—Part IV

Unheated separate-sludge digesters have a field of usefulness for small communities and institutions. Routine operating attention on an intelligent level must be provided to produce satisfactory results. Such operation coupled with proper design will produce sludge of satisfactory quality.

Fig. 19.—Heavy-lid Type of Manhole Cover, Such as Used at Torrington, Conn., Has Several Advantages.

TABLE IV

Analyses of Sludges from Unheated Separate Sludge Digestion Tanks

Sample No.	% Moisture	% Fixed Solids	% Volatile Solids	Alkalinity, ppm.	Color	Odor
1	93	61	39	3500	Brown	Tarry
2	70	82	18	1600	Black	Tarry
3	95	56	44	3200	Brown	Tarry
4	91	46	54	630	Black	Tarry
5	95	50	50	1000	Black	Tarry
6	87	59	41	4400	Black	Tarry
7	90	51	49	900	Black	Tarry
8	93	43	57	2600	Brown	Tarry

Fig. 20.—The New London, Conn., Plant.
An example of insulated digesters with brick jackets.

PART V

Heated Sludge Digesters

Of the various methods for the digestion of sewage solids, none affords such precise control as that provided by heated digesters. Engineers strive for exact regulation of engineering processes, so it is logical that the sanitary engineer has developed present-day separate sludge digestion to a highly specialized degree.

Considerations in Adopting Heated Digesters

Plant Location

A study of Fig. 12 illustrates why heated digesters have such a wide field of usefulness in modern sewage treatment. In spite of the nearness of houses, no odor complaints during 16 years of operation have ever been received by those operating this plant. That such plants can be built in congested areas is an important advantage to the consulting and designing engineer faced with either limited land areas or the need of economizing on outfall sewers by using a central location. Plants in built-up areas treating septic sewage should practice prechlorination, however, to control those odors which emanate from the sewage itself and possess the power of travel.

Connected Population

The writer has in earlier articles in this series suggested other types of digestion units for connected populations up to 5000. Imhoff tanks, in my opinion, continue to compete with heated digesters up to population loadings of 15,000 to 20,000. Provided that the raw sewage solids are responsive to digestion, there are few treatment plants in the higher population range that are not amenable to heated sludge digestion. In the case of very large plants, it is argued by some that a large digestion volume results in too high an initial outlay of capital and that its omission avoids an additional step in sludge treatment, which otherwise can be accomplished by vacuum filtering the raw solids and incinerating. On the other hand the author has previously discussed in *Water & Sewage Works*[1] the multitude of benefits derived from digestion, and reiterates his belief that most plants should enjoy its advantages.* Furthermore, the humus in digested sludge is sorely needed by many of our soils and efforts should be exerted to so direct its disposal to the practical limit.

*This statement applies to primary and humus sludges, and not to the vacuum filtration of raw activated sludge, which after heat drying frequently has a ready market as fertilizer.

Character of the Sewage

The raw solids in some sewages cannot, unfortunately, be digested, because of the presence of harmful industrial wastes in toxic or excessive quantities.

The wastes from metal processes such as copper, chromium, nickel or cyanide are bacterial inhibitors beyond certain limiting quantities.

Reported limiting quantities in the literature have varied. Copper or cyanide should probably not exceed 1 ppm. in the raw sewage; chromium not over 25-30 ppm. in sewage; nickel not much over 500 ppm. in the sludge, which may limit the quantity to 2 or 3 ppm. in raw sewages. These materials tend to be cumulative in the sludge, thus building up to hundreds of ppm. in the digester's contents with attending slow digestion and falling off of gas production.

While liming of digesters coupled with long digestion periods will sometimes permit a fair degree of digestion with some of these wastes, their exclusion or rigid control is imperative for satisfactory digestion.

Formaldehyde used as a disinfectant in some industrial processes is also an inhibitor of sludge digestion. Gilcreas recently reported digestion difficulties caused by formaldehyde following its use as a vat disinfecting agent in the manufacture of penicillin.

Fibrous wastes cause a mat of thick scum to form in digesters. This scum resists digestion; it increases in depth, thereby reducing the effective digester volume; it retards gas release; it limits the supernatant liquor zone; it causes failure of tank mechanical stirrers and often necessitates a periodical emptying of the digester contents. Wool fibre and hat fur are typical of these wastes. In Connecticut some plants have satisfactorily digested raw solids containing these wastes in the raw sewage where fine screening of raw sewage is used. Such screens have slot openings of 1/32-inch and remove substantial quantities of fibre from the sewage flow. Special digester facilities for scum removal have also been provided, including scum stirring mechanisms and means for direct removal of scum by draw-off pipes and access manholes.

Canning and other industrial wastes affect digestion in varying degrees. Many wastes are bound to become a problem in our modern industrial age and all communities must take steps to work with industry in pre-treating or removing such wastes as are harmful to sludge digestion, not to mention the effect certain wastes may have on other plant processes or on the collecting sewers themselves.

Sludge Gas Utilization

The utilization of the gas produced by sludge digestion, coupled with the utilization of the digested sludge as a soil conditioner, undoubtedly has more popular appeal than any other phase of sewage treatment. Probably the first use of sludge gas was in 1895, when Mr. Cameron, Borough Engineer of Exeter, England, used it in a street lamp for lighting. The many uses for sludge gas at heated sludge digestion plants argues well for the use of the process. Such uses include:

1. Heating of digesters.
2. Heating treatment buildings.
3. Laboratory use.
4. Operating gas engines, which in turn are coupled to sewage pumps, air blowers or electric generators.
5. Source in whole or part for incineration or drying of sewage screenings or sludge.
6. Gas refrigeration.
7. Lighting.
8. Motor fuel in trucks. (For this purpose the gas is compressed to about 5,000 lbs. per sq. in pressure. About 10 cu. ft. of gas will drive the average truck one mile, hence 170 cu. ft. is equal to about one gallon of gasoline.)

The major uses in this country are for heating of digesters and buildings and as fuel for gas engines. Now that dual-fuel engines have been developed which will operate with either sludge gas and fuel oil or sludge gas and gasoline, the use of such engines can be expected to increase at the smaller digestion plants (connected populations of 25,000 to 50,000).

Operating Personnel

The qualifications of operators for plants employing separate sludge digestion with gas collection have been detailed by the Operators' Qualifications Committee of the Federation of Sewage Works Associations[2]. Plants of this type serving communities of moderate size (5000 to 25,000 persons) can be capably operated by men having previous mechanical experience such as mechanics, plumbers, electricians or factory foremen. While the men themselves may feel lacking in the necessary chemical and sanitary knowledge to successfully operate such a plant, the writer's experience has clearly indicated that these men can be readily trained for the necessary laboratory work and in the theory of the plant's processes. Such men are to be preferred for the smaller communities, since they have the "know-how" for "keeping the wheels moving." With instruction by local technical personnel, consulting sanitary engineers, or state supervising agencies, such men, if possessed with a reasonable amount

of schooling, initiative and tact, make excellent operators.

Summary of Influencing Factors and Considerations

1. A central plant site can be chosen relatively near houses.
2. Connected populations of 5000 (sometimes less) and up can be served with all the advantages that are gained by digestion.
3. The sewage must not contain industrial wastes harmful to the digestive process.
4. Sludge gas utilization can be practiced.
5. The chief operator must be mechanically trained, have a reasonable amount of schooling (at least equivalent to high school graduation), and show initiative and ability to handle men. Large plants should be in charge of technically trained personnel.

Deciding Type of Layout

The designer of heated digesters is faced with a dilemma at the start: "What type of layout shall be select?" Among the choices are:

1. To provide but one, or more than one, digester at small plants.
2. To use rectangular or circular tanks, with or without stirring of the tank's contents. The stirring equipment may be slow or high speed and may be accomplished by mechanical devices within the digester or by recirculating pumps located outside the digester.
3. To operate the system in parallel or series (i.e. single or two-stage digestion).
4. To furnish fixed covers, floating covers, gas holder covers, open top secondary tanks, or a combination.
5. To heat all tanks or only the primary units. There is also a wide choice of heating methods.

General comments on these lay-outs follow:

How Many Tanks?

Limited construction funds for small plants often require the use of a single digester. However, two tanks are desirable for flexibility in operation and for continuance of digestion whenever one tank may need repairs or emptying. When existing septic and Imhoff tank plants are converted to separate-sludge digestion type plants, an economical and very workable scheme used at several Connecticut plants has been to provide on heated digester with supernatant overflow and/or digested sludge storage in the old septic or Imhoff tanks. Such tanks have yielded overflow liquor of excellent quality, operated without nuisance, and provided a storage space for sludge during the winter or other periods when sludge drying facilities were not available. Old tanks used in this manner should be covered with treated wooden planking or perferably precast conrete slabs.

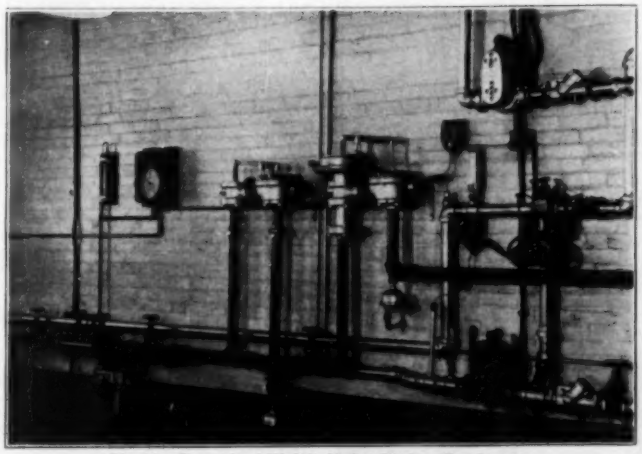

Fig. 22.—Example of Well Laid-Out Modern Gas System.
Note meters, flame traps, pressure regulator, pressure gage, condensate traps. Also shown is part of the hot water circulating system to digester.

Another money-saving arrangement for some plants is the use of an open top circular secondary digester adjacent to the heated tank. The top of open tanks should be 12 or more feet above grade, or they may be located on a slope above surrounding structures, to dissipate any local odors. When properly operated and adequately designed, such tanks emit no odors of a travelling nature, serve as sludge storage basins during northern winters and discharge overflow liquor of good quality*. The scum in such tanks is readily accessible for breaking up or withdrawal when required.

*What constitutes good quality liquor will be discussed later under Part VI.

When only one digester is built, a flexible piping arrangement that allows for emergency sludge storage in one or more settling tanks is suggested and may prove very useful.

What Type Tank?

Although the circular tank has the advantage of greater depth for sludge and supernatant separation, the writer has observed very satisfactory results from heated rectangular digesters, equipped with chain-drive slow stirring mechanisms. The designer's choice is sometimes dictated by the pattern of the land at the construction site.

Rectangular tanks equipped with fixed overflow liquor take-off should be provided with a take-off having at least two and preferably more overflow elevations. One should be about 3 feet below the maximum water surface; the other about 6 feet below. Such a design permits the drawing of supernatant from the zone of greatest clarity. The top action in a slow mechanically-stirred rectangular digester has been observed by the writer to soften and sink the scum or to concentrate it in moderate depths at the raw sludge inlet end, which is at the opposite end from the supernatant draw-off manhole. Here can be located large rectangular manholes from which, if required, the scum can be removed manually or mechanically. The bottom stirring action of the mechanism also aids in uniform gas production and in moving any grit in the sludge to the sludge withdrawal hopper, thus preventing its build-up on the tank bottom with resulting decrease in available digestion tank volume. Circular tanks equipped with slow stirring scum and sludge mechanisms have similar advantages except that the scum layer is not so effectively separated from the point of overflow.

It is significant that slow stirring mechanisms for both circular and rectangular digesters, so commonly installed in the '20's and early 30's, have produced in many plants a well-digested heavy sludge, effective control of scum, and automatic grit removal. In contrast floating covers and rapid mechanical stirrers have failed in many cases to prevent scum build-up and of course do not gravitate heavy bottom solids to the sludge draw-off piping.

Fig. 21.—The Compact Plant of Norwich, Conn.
The operating building being built against the wall of the digester, provides an economical digester operating gallery.

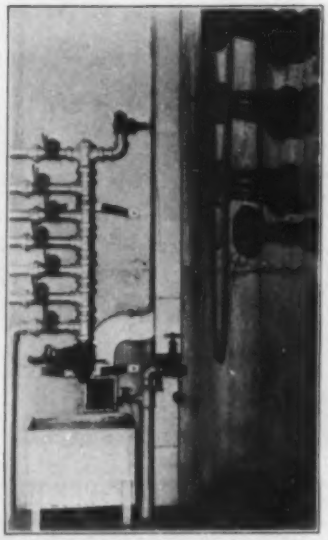

Fig. 23.—Section of a Digestion Tank Operating and Control Gallery.
Note digester contents sampling and supernatant zone finding lines, and sampling sink on left. On right is the battery of supernatant draw-off valves and lines, the upper valves being operated by chain pull.

Recirculation of supernatant over the scum layer and modifications in high speed stirring devices are now proposed for scum control. The latter is in the testing stage, while installations of the former have been made. Both need demonstration and operating results at sizable municipal installations. Let us hope these results will be favorable because both methods will permit maintenance of the equipment from outside the digester. The slow-stirring type of scum and sludge equipment, as good as it is, does require emptying of the digester for major repairs, with attending inconvenience and occupational hazard. Adjustment of chains, mechanical wear, corrosion, painting and other repair work generally requires that slow stirring equipment be inspected every 3 to 5 years. With luck some plants have gone longer. Maintenance costs and the initial cost of slow-stirring equipment have predisposed many designers against this type of tank.

Regardless of whether or not tank recirculation or stirring equipment is provided, some positive means for scum control is needed for heated digesters. Such means can be furnished without mechanical aids, although such aids, if effective, are much to be preferred. Some concrete suggestions for solving this problem will be given later.

Parallel or Series Operation?

In the early days of separate sludge digestion, parallel operation, in which all digesters received about equal loadings of raw sludge, was generally practiced. About 1934, series or two-stage digestion began to be commonly employed. Three-stage digestion has also been used in some instances.

Parallel operation assures daily feeding of the bacteria and micro-organisms in digesters, thus aiding in maintaining an equal and steady flow of sludge gas from all units. Foaming tanks can be rested and operation is somewhat simpler. Series operation concentrates the scum problem in the primary tank; the secondary tank sludge can be concentrated, and thereby may contain a higher percentage of dry solids; but most significant is the reduced solids in the overflow liquor. The better quality of secondary tank overflow usually secured from series operation results from a cooler tank, lower rate of gas production, easier control of the solids loading, and less scum accumulation. Many designers provide the benefits of both methods of operation by installing a flexible piping arrangement, which permits use of either parallel or series operation. While there is a slight trend back to parallel operation at present, the writer believes a flexible layout is again highly desirable whenever two or more digesters are built.

What Type Cover?

All types of tank covers work satisfactorily. From the safety standpoint fixed-cover tanks must be kept full to the point of overflow. This may be accomplished in two-stage operation, by use of a gas holder riding on the gas system and filling any void created by drawing bottom sludge, or by a float-controlled device that will admit either plant effluent, or a water supply not cross-connected with a potable supply, whenever the digester level drops. Some of the older fixed cover tanks, of which many still exist, lack such positive means of preventing explosion hazard, and dependence must then be placed on carefully executed operating procedures.

Floating covers, within their limits of travel, are not only safe, but permit drawing of supernatant liquor following quiescent periods between raw sludge pumpings or digested sludge removals. The gasholder type of cover is commonly used on secondary tanks with series operation, but can be readily adapted to single digester operation. They are useful at small plants for storage of peak gas yields which can then be burned at night when gas production is frequently low. Such covers are also useful at plants needing auxiliary heat for incinerators, or for continuous gas engine operation. In addition, separate gas storage tanks of either cylindrical or spherical shape (see figures 15 and 16) are used at the larger plants.

How To Heat?

In series digestion usually the primary tank only is heated. Even in northern climates, however, it is not unusual for properly insulated secondary tanks to maintain temperatures of 70° F. or better from the heated transfer liquor. Again in the interest of flexibility, there is a tendency today to provide means for heating both primary and secondary tanks.

Heating methods include hot water coils around digester peripheries; removable hot water coils hung near the center of digesters; hot water coils enclosed in the digester walls; Keefer's Kemp submerged gas burner[10]; live steam heating of raw sludge; direct addition of live steam or hot water to the tank contents, and heat exchange units located outside of digesters and through which raw sludge and tank supernatant are heated and recirculated by means of a pump. Miles, Rudolfs, Rawn, Bacon and Ludwig have recently discussed the subject in detail.[11]

The great majority of digesters in use today are provided with interior hot water coils. The writer has observed good results with peripheral hot water coils, as well as with coils hung near the tank centers. By proper control of the in-going water temperature some plants have experienced continuous use of such coils for periods of 15 years and more. Some tanks have yet to be emptied for repairs or coil scraping. Many tanks have been heated for 10 years by this method and the coils are still producing satisfactory results.

The most positive assurance that safe ingoing temperatures are not being exceeded is to provide a *recording* temperature thermometer for each water heating circuit. A 24-hour chart on which is plotted the ingoing and return water temperatures gives the operator a permanent record for review, and from which he can make any necessary control adjustments. In addition such recording thermometers show by the temperature differential between the "in" and the "out" water, how effectively the coils are transferring the heat from the water to the digester contents. As the coils become incrustated, the differential becomes less and the need for coil scraping will become apparent. Funds might rather be spent for hot water temperature recorders than on the temperature of the digester's sludge, which varies but slightly in a single day under usual conditions. Dial thermometers, which are read several times daily, will suffice for sludge temperature readings at most plants.

A word about periphery coil location. In many early designs the coils were placed too near the tank bottom. The active zone of digestion should be heated; not the dead sludge. This suggests a coil position starting about one-third the tank depth from the bottom and extending to about the mid-

Fig. 24.—A Digester with Fixed Cover.
Is equipped with five manholes for access to scum, only four of these showing however. Note the heavy manhole lid shown at close range in Fig. 19.

point of the tank. In Hartford, Wurts placed three sets of coils in the tanks, one near the top, one at the center, and one near the bottom. Hot water can be admitted to one or all sets. This permits heating of scum in winter, as well as providing a wide range of tank temperature without changing the temperature of the ingoing hot water.

The newer heat exchange units located outside of digesters are highly desirable and should prove more satisfactory than coils within the tanks. Kunsch at Urbana, Illinois, with one of the earliest municipal installations reports good results but points out that a single digester may produce poor overflow liquor in winter. The mixing of the tank contents by the recirculation method for long hours (as will be necessary in northern climates) creates this problem. A secondary tank or other means for liquor settlement or treatment appears the obvious answer to this difficulty.

Regardless of the method of heating digesters, a stand-by fuel in addition to sludge gas should be available, both for starting up of the plant and for auxiliary or emergency fuel needs. Fuel oil, coal, and manufactured gas have all been used in Connecticut with satisfactory results. Gasoline is another stand-by fuel where dual-fueled gas engines are employed with circulation of the jacketed hot water to buildings and digesters.

Manufactured gas and sludge gas are automatically mixed and burned in one boiler at two Connecticut plants. Where gas production is ample for winter heating of tanks and buildings, a boiler equipped for burning either sludge gas or fuel oil permits continuous heating if the gas supply fails. Fig. 18 illustrates such an arrangement. For small plants, producing insufficient gas for winter demands, two boilers, one on sludge gas and one on fuel oil or coal, operated in series, make use of all sludge gas produced and are therefore economical in operation. Fig. 17 illustrates the method.

Features of Design

A digestion tank is like a railroad station—something is continually arriving or departing. Digesters might be considered as the "social hub" of a sewage plant, receiving raw solids (mixed company indeed), displacing liquor, producing gas, liquefying colloidal matter, breaking down the volatile solids to fixed solids, and concentrating digested solids for removal. Is it any wonder over-worked digesters spout foam, discharge sick looking (and sometimes sick smelling) sludge or yield gravy-like supernatant liquor?

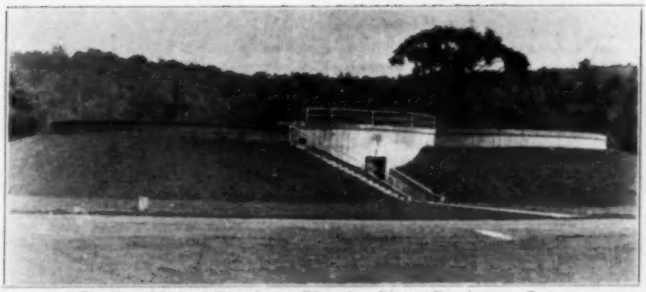

Fig. 26.—Modern Two-Stage Digestion Plant—Torrington, Conn. An operating gallery separates a heated fixed-cover primary digestion tank and the unheated open top secondary digester.

Required Capacity

What is an overworked digester? Opinions vary, but most designers and operators agree that past capacity allowances need liberalizing. A reluctance to raise digester capacities stems from a desire to hold down plant costs. Such economy may be short sighted, however, when nuisance or operating difficulties result. The capacities given herewith are based on the cu. ft. of liquid volume per equivalent capita served. Equivalent per capita allowances embrace the load contributed by industrial wastes as well as the actual connected population. Unless the sewage to be treated is unusually strong or has other abnormal characteristics, per capita allowances appear to be a sound basis for design. The dependability of such allowances leans heavily, however, on the accuracy of population estimates and a careful survey of the character and quantity of industrial wastes to be handled.

Rankin[6] has recently suggested that the volume of digesters might be based on the volume of raw sludge input and its detention in the digester. These factors he finds are based on a study of annual reports of operation at existing plants, and bear a close relation to tank performance as measured by volatile matter reduction. He observes that digesters having detention periods of less than 30 days experience supernatant trouble, while those with 60 days or more detention seem to have no troubles. Between these periods the data are inconclusive. This basis for design would appear to warrant careful study, but without supporting operating data the volume of raw sludge to be handled may vary considerably from estimates, thus making the required digester volume a difficult decision in designing new plants.

Suggested Capacity Allowances in Digesters for Connected Equivalent Population

Type of Sludge	Cubic Feet per Capita	
	Minimum	Preferable
Primary	2.0	2.5 to 3.0
Primary and humus	2.5	3.0 to 3.5
Primary and activated sludge	4.0	5.0

Allowances appreciably below the minimum figures of the table will usually result in one or more operating difficulties.

Control Galleries

The first digestion tanks were often built with either the control valves and connecting piping buried in the ground near the tanks, or located in a deep chamber adjacent to the tank. Being accessible only through a standard manhole with cramped interior quarters, these chambers created an occupational hazard. Control galleries at or near grade level, built between and adjacent to the tanks, furnished ideal housing for these valves and pipes, as well as for sampling sinks, sludge temperature thermometers, recirculating pumps, sludge pumps, gas compressors, and a portion of the sludge gas safety devices—in particular the main gas meter, waste gas meter, flame trap and pressure regulator for the waste gas line and the condensate traps.

Control galleries should be well ventilated by natural draft or mechanical exhaust or both. Non-sparking motors, explosion-proof switches, wiring and lighting fixtures should be specified. The design should conform with the requirements of Article 32 of the National Electric Code for Class A hazardous locations.

Sampling Sink

A sampling sink in the control gallery enables an operator to obtain samples from various levels in the digesters with a minimum of effort, and independent of outside weather conditions—(see Fig. 23). They also provide, as has been previously mentioned, a convenient and inexpensive means for the slow return of supernatant overflow liquor to the raw sewage. Soundings made with sludge samplers or pitcher pumps from manholes in the covers of digesters involve laborious and messy work.

The sink should be at least 18 inches deep, ample in area, and furnished with water or effluent under pressure for back-flushing clogged sampling pipes and for rinsing. No cross-connections between such flushing

(*Continued on page* R-162)

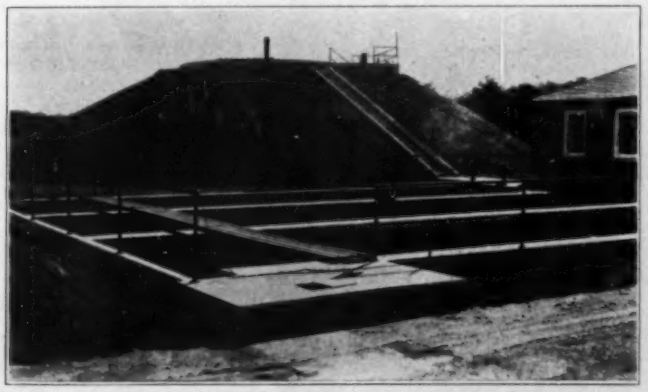

Fig. 25.—Typical Separate Sludge Digestion Plant—Putnam, Conn. Heated digester with floating cover and protected by earth embankment.

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View at right shows a 16 MGD Water Treatment Plant, for the Fall Creek Plant of the Indianapolis Water Company, Indianapolis, Ind., which is completely equipped with Jeffrey FLOCTROLS and Sludge Collectors.

Plant extensions which will double the capacity of this plant are now being supplied with Jeffrey Equipment.

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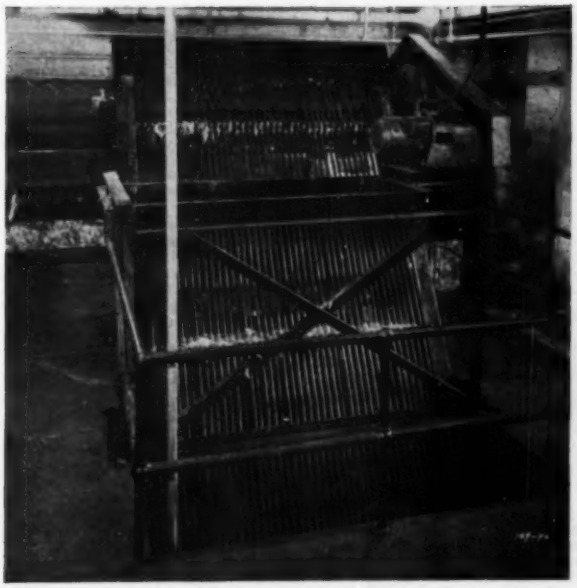

Jeffrey Mechanically Cleaned Bar Screen

View at left shows a Jeffrey back-cleaned type of screen at the Dayton, Ohio, Sewage Treatment Plant.

Based on a new principle of design this type of Jeffrey Mechanically Cleaned Coarse Bar Screen is practically fool-proof.

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Operation by time control is recommended but also can be by differential float. Provision is made for continuous operation if desired.

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Jeffrey patented JIGRIT Washer is now built in three sizes ranging in capacity from one ton to fourteen tons per hour, offering these advantages:

1—Removes 90% of putrescible solids.

2—Washed grit contains no organic seeds or unsightly material—can be used as fill without creating a nuisance.

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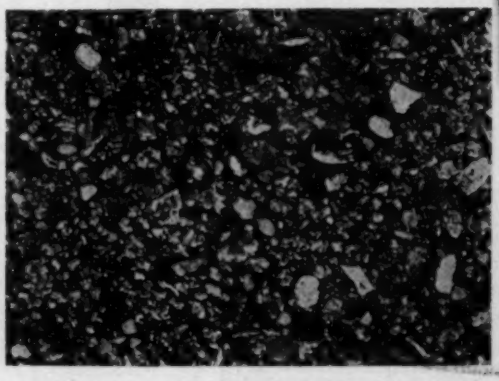
Jeffrey No. 1 JIGRIT Washer

Magnified view of unwashed sewage grit



Magnified view of washed grit after passing through Jeffrey JIGRIT Washer

Fig. 27.—Recording Instruments on Gas System.
Always an operation aid are such instruments. These record gas pressures and volume of gas produced and volume wasted.

(*Continued from page* R-159)

water and any potable water supply should be made. The sampling pipes, tapped from the supernatant and sludge draw-off pipes on the digester walls, should terminate over the sink. The pipes should have a minimum diameter of 1¼-in. to reduce clogging with heavy scum. Wrought iron or brass pipe is generally used. A numbering system, color scheme or other identification for each sample pipe is a convenience. The pipes should have threaded ends for attaching a back-flushing hose, or the back-flushing water can be individually valved to each sampling pipe behind its quick-opening sampling valve.

These sampling pipes are frequently taken off the digester supernatant and sludge draw-off pipes between the digester wall and the controlling gate valves. Samples are then procurable without opening and closing the large valves. This arrangement, however, places the digester hydraulic head on the quick-opening or small gate valves at the sink end. Although with good workmanship no difficulty may be experienced for some years, it is advisable to place a small gate valve on the digester side of these sampling lines. Then if the sink valve breaks or cannot be shut tight, or a complete clogging of the sampling pipe has occurred, the line can be closed, disassembled and repairs made. Taking off the sampling pipes beyond the large digester piping valves is another solution, but this requires opening of several large valves when sampling various levels of the tank.

Supernatant Draw-Offs

Every digester should be provided with at least two supernatant overflow liquor levels and preferably three or four. One leading sanitary engineering firm designs its digesters with decanting pipes practically the entire depth of the tanks at intervals of 2 to 3 feet. A waste of money? Not if you have a supernatant or scum problem! Secondary digesters connected for series operation are an exception, although even these should have two top overflows about 3 or 4 feet apart in case of scum clogging. Both supernatant and sludge piping from digesters should be not less than 8-in. in diameter. Valves not accessible from the control gallery floor can be operated by a wheel-and-chain mechanism—(see Fig. 23).

In recent years a patented device for drawing off and selecting the best supernatant liquor has been developed. By its use, conventional supernatant draw-offs are considered unnecessary, but the device needs further demonstration at sizeable municipal installations. In any event, several conventional draw-off pipes are still desirable for the removal of scum, as discussed further on.

Disposal of Supernatant

Although the volume of overflow liquor in the averge separate sludge digestion type plant is only 0.2 to 0.3 percent of the total sewage flow, and will run around 2000 gallons per million gallons of sewage treated (this provides no allowance for sludge pumpings from secondary treatment processes), even such a moderate return to the raw sewage flow at the smaller treatment plants is frequently a major operating problem, because of the reduced dilution afforded by the *instant hourly flow* at these plants.

Erickson[9] in an excellent paper on "Treatment and Disposal of Digestion Tank Supernatant Liquor" presented by Langford before the New England Sewage Works Association stated in this connection:

"Despite the exercising of care by plant operators to draw off only the best liquor, it is usually still high in solids, great in volume and it imposes a heavy B.O.D. and solids load on the portion of the plant to which it is returned. Due to its high B.O.D. and solids content and probably to the specific nature of its bacterial flora, supernatant liquor has a tendency to cause disturbance of the primary settling tanks. This causes a sludge of higher moisture content to be transferred to the digester and results in a greater volume of supernatant liquor to be returned. Thus a self-pyramiding cycle is set up."

In addition to these remarks it should be pointed out that digester overflow liquor has a high chlorine demand, which requires an increase in the chlorine dose for satisfactory sewage disinfectiton, odor control, and other chlorination processes.

For these reasons it is desirable, particularly at small and moderate sized plants, to provide in the design for one or more alternate methods of supernatant disposal. Suggestions follow:

1. Return to the raw sewage is the commonest method of handling. The liquor should be returned at a slow rate to *all* of the sewage flow to obtain maximum dilution. Return rates should be kept low by providing means for drawing supernatant through small sampling sink draw-off valves instead of the large valves on the digester supernatant piping. This method of removal is also suggested for unheated separate digesters. At least one manufacturer has a rate control device for slow and constant rate withdrawal of supernatant.
2. Discharge to the sludge drying beds or lagoons with subsequent filtering. By proper operation this is a very practical method of handling supernatant liquor at small plants. Odors can be controlled.
3. Pre-settling in abandoned septic or Imhoff tanks in re-built plants (see comments under "How Many Tanks" above) or in special settling tanks. After pre-settling, the effluent should be returned to the raw sewage.
4. Patented treatment processes such as atomized aeration and settling.

The writer having had no experience with the last named installations is unable to report on them at this time.

Tank Cover Manholes

In addition to the usual small 6-in. manhole covers over sounding entrances for scum or sludge or for temperature readings, and the inspection manholes for heat ex-

Fig. 28.—A Modern Sludge Pumping Unit.
On right is the sludge sampling device on the discharge side of pump.

changers, stirring equipment and gas domes, 24-in. diameter manholes should be provided for cross-circulation of air when a tank is entered, and for access to tank scum. These large manholes should be at least four in number. One manhole should be directly over the supernatant piping. Another should be at the opposite side of the cover and near the tank wall to serve as a means of access to manhole rungs down the tank's interior wall. The other two should be 5 or 6 feet in from the periphery of the cover to provide greater access to the scum and should be spaced opposite each other and equidistant from the other two manholes.

There has been a lot of discussion of scum in this series. Scum accumulations are a real problem in separate sludge digestion tanks. Control of this scum has not been completely solved, except that properly designed and operated water sprays, or slow-stirring types of scum mechanism are usually successful controls.

Some engineers have installed elaborate piping lay-outs under the roof of fixed cover digesters for scum control. Supernatant is pumped with a recirculating pump to nozzles in this piping. From these nozzles the heated supernatant under high pressure is sprayed over the scum, softening and sinking it. If properly designed *and regularly used* by the operator, scum build-up should be effectively prevented.

Until the newer controls are tried and proven, the writer suggests more manholes on digester covers. Then if scum does accumulate, it can be broken up with water or sewage or supernatant under pressure through the four manholes described above. The scum can then be drawn off to vacuum filters or sludge beds in a fluid condition through the flexible supernatant draw-off piping already recommended. The writer has seen as much as 5 feet per day of heavy scum removed from digesters by this method. Granted, the method will not prevent a scum build-up, but if a scum accumulation defies settling by heating or other means, this method affords a sure means of removal. The manholes normally furnished with prefabricated digester covers will prove insufficient in number for scum removal by this method.

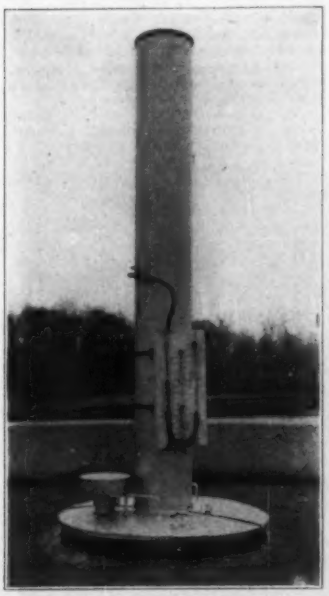


Fig. 29.—Portable U-Gage For Measuring Gas Pressures This one is in use at Milford, Conn.

Fig. 30.—Open-top Unheated Secondary Digesters at Torrington, Conn. With scum 9 inches thick, but soft and black, there have never been any objectionable odors. In reality it is floating digested sludge, beneath which is good quality supernatant liquor.

A unique type of manhole cover is pictured in Fig. 19. This cover, weighing about 400 pounds, sets on a gasketed rim without fasteners and its weight is depended upon to prevent the escape of gas. It is easily removed by inserting an iron bar through the manhole cover rings, and lifting it to one side by leverage action. Such manholes are also a safety precaution as undue pressures caused by gas pipe stoppages, closing of supernatant valves, etc. will be relieved at the manholes rather than causing structural damage to the cover, the flooding of gas pipes with liquor, or other harm. The manhole illustrated is one of a number installed at Torrington, Conn.

Importance of Tank Insulation For Northern Climates

Many of the early digesters were poorly insulated. High ground water around a digester, as well as poorly contructed walls and covers, will cause heat losses.

To avoid ground water the tank can sometimes be built mostly above ground, a dry location can be sought, or drainage tile employed. Earth embankments around digester walls are not too efficient insulators, tend to settle, and are hard to keep attractive. For operators who tire of attempts to maintain trimmed grass on such embankments, the planting of honeysuckle is suggested. This grows easily, makes a dense cover, ordinarily requires no spraying, pruning or special maintenance, and yet holds the earth and looks fairly presentable.

Figure 20 shows two digesters built with insulated brick walls to retain the tank's heat. Various wall materials are being used in the newer tanks, including brick, concrete, or stucco over hollow blocks or tile, and with insulation provided by air spaces, rock wool, aluminum foil or other suitable materials.

Tank covers also need better insulating. Winter readings made by the writer with a maximum recording thermometer have shown differences of 10° to over 20° F. between the sludge zone and scum zone in many tanks. Much heat loss was apparently occurring through the tank covers. Cold scum digests slowly and this fact is undoubtedly a factor in its more rapid build-up in winter.

Gas Collecting System

The recommendations of the Sewage Works Federation's Committee on "Occupational Hazards in the Operation of Sewage Works"[3] should be followed. In particular a minimum diameter of 2 in. for gas piping should be adopted, and all pipes should be laid on a good foundatiton, protected from freezing, and pitched to *approved* condensate traps. Do not use home-made traps or any of the so-called automatic types. The gas piping appurtenances (gas meters, pressure regulators, condensate traps, and sometimes the flame traps) should be grouped together in a well ventilated explosion-protected structure such as a digestion tank control gallery or separate room with outside entrance only. All units except flame traps should have by-passes. Fig. 22 shows a well planned lay-out.

Waste gas burners should be safely located. Prefabricated digester covers are equipped with pressure and vacuum reliefs. Locally designed and built covers should be likewise equipped. Explosions are still occuring from U-tube water-seal type traps on gas lines. These are not safe and should never be used. Vents from any part of the gas system to atmosphere should never be permitted to terminate within a confined space. Even the atmospheric diaphragm vent on boiler pressure regulating valves should be vented to outdoors. As a word of caution, such diaphragms have been found to crack with age.

Designing engineers have a responsnbility to provide *detailed* drawings of gas lay-outs for the guidance of the artisans, and not depend on the judgment of local workmen in the important matter of making correct gas piping hook-ups.

PART VI

Operation of Heated Sludge Digesters

In this Part VI the following topics will be discussed:

1. Liming of digesters.
2. Starting new tanks.
3. Operating an established digester.
4. Controlling scum.

Fig. 31.—Portion of a Modern Separate Sludge Digestion Tank Plant. (Note nearness of houses.)

5. Handling of supernatant overflow liquor.

6. Safety precautions.

The reader is referred to any of the numerous pamphlets or books describing the details of the digestion tank operation. The present discussion is limited to those phases of operation that the writer's experience has shown to be of particular importance.

Liming of Digesters

Liming of septic tanks, Imhoff tanks and unheated separate digesters has already been suggested in previous articles of this series for certain operating conditions. It is also suggested under *certain* conditions for heated digesters. In the light of recent research this may be considered unsound, and some have gone so far as to recommend against all liming. Lime has undoubtedly been used too indiscriminately in the past. In some instances the use of lime has reduced methane production and resulted in lumping of lime in tank bottoms, not to mention the expense and the work involved in its application. Checks with and without lime additions are now in progress at several Connecticut plants where an apparent need for liming has been indicated in the past.

Regardless of the good and the bad of liming, the writer still recommends lime for overloaded digesters (including Imhoff tanks), and for starting up digesters without seed, because the method has aided in preventing foaming and avoiding nuisance at numerous plants over a period of nearly 20 years. Reports of foaming tanks, odorous sludge and poor overflow liquor are not infrequent at plants starting under full load without lime. If the digesters can be fed raw sludge gradually until seeding material is built up and are not subsequently overloaded, lime may well be omitted. The latter procedure is, however, not always practical nor possible.

Starting New Tanks

Efforts to seed digesters at new plants with ripe sludge have not usually been successful because of an insufficient volume of ripe sludge. It will rarely prove economical to haul the large quantity of digested sludge required for starting the average-sized digester, because such quantity should be not less than 20 per cent by volume of the digester's capacity.

In 1933 the writer reported on a method[8] of starting digestion tanks, which avoids foaming, controls odors, and produces both seed sludge and burnable sludge gas within 30 days. This method has been used repeatedly with consistent results.

The method in brief:

1. Fill the digester to the overflow level with sewage (in the case of a floating cover digester, until the cover rises) before adding any sludge. The slow filling of new (empty or partially filled) digesters with raw sludge is an occupational hazard of the first order, because of the possibility of sludge gas and air forming an explosive mixture, and should never be practiced. In other respects slow filling would have much merit, as there is no foul overflow liquor problem, the sludge becomes more concentrated, and mixing of raw and seeded solids is easily accomplished.

2. Heat the tank contents to at least 80° F. This temperature rise is attained before adding raw sludge. Maintain a temperature around 80 to 85° F. for the first thirty days, then increase the temperature to between 95 and 100° F., if possible, for future operation.

3. Add the daily full load of fresh raw solids mixed with milk of lime. If the tank can receive rest periods or very light feedings of raw solids, liming can undoubtedly be omitted. Most plant operators are unable to follow this procedure, because only one digester is available, and plant processes cannot be shut on and off without nuisance, or for other varied reasons.

Facilities of one kind or another are usually available for adding milk of lime to the raw sludge. The primary settling tank skimmings-well is one convenient means, and at least one manufacturer's design (with circular tanks) permits mixing of raw sludge and lime at this point. Otherwise the lime slurry can be pumped to the digester with skimmings and sewage after pumping sludge. Another means for mixing lime with raw sludge, which can be cheaply and quickly installed by an operator of a small plant, is to erect a small lime feed-tank with shut-off valve on the suction side of the sludge pump. If pipe sizes are adequate and discharge distances relatively short, a fine grade of hydrated lime powder, such as finishing lime or spray lime, can be substituted for the milk of lime. Such lime is dumped directly into the mixing chamber and pumped with sewage or sludge to the digester. While preparing a milk of lime suspension involves more labor, its use will preclude pipe stoppages and lime pockets, and results in better distribution of the lime throughout the sludge.

If no other means for adding lime is available, dry lime can be mixed with the digester supernatant in the cover manholes, or preferably milk of lime can be added through these manholes at the top, and into a lower level with rain leader pipe.

4. The quantity of lime will vary at each plant. A moderate sized plant, say one in the population range of 25,000, may require six to eight 50-lb. bags of lime daily at the start. This will taper off after 2 or 3 weeks until none is required. The important thing is to maintain the pH around 6.6 to 7.0 by regular lime additions. Permitting the pH to drop to 6.0 and lower leads to trouble. Rudolfs at the New Jersey Experiment Station confirmed this many years ago in the laboratory; the writer has since confirmed it many times in the field. It must be realized that a sludge of pH 6 is ten times more acidic than a sludge of pH 7.

5. Circulate the bottom limed sludge to the top or center of the tank several hours daily at the start.

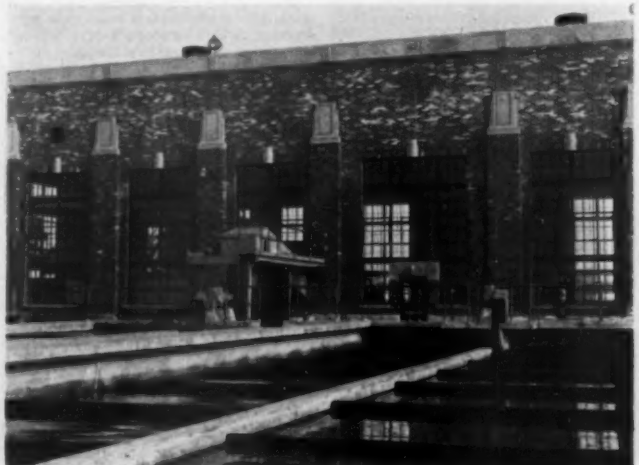


Fig. 32.—Hartford, Conn.—Digestion Makes Possible the Use of Elutriation Tanks for Washing Sludge.

For a short time the overflow liquor and gas will be vile smelling, but in about a month this odor will decrease, the gas will burn, black digested sludge will begin to build up, and the starting headaches of many an operator will be avoided.

Operating an Established Digester

1. Add concentrated fresh raw solids frequently. Do not permit primary sludge to become septic. Fresh solids have less effect on the total alkalinity balance in digesters. Regular frequent feedings of the bacteria and micro-organisms in the tank are necessary; they must be fed gradually and frequently if they are to thrive and do their work effectively.

By introducing only concentrated sludge (whether primary, trickling filter, humus, waste activated, or chemically precipitated) the volume of overflow liquor will be reduced. Large volumes of overflow liquor add to the burden of primary settling tanks, increase the chlorine demand of the plant effluent and create demands for oxygen. Water streaks in the pumped sludge are an indication that it is too thin. Some plant operators weigh samples of the raw sludge on a pan balance and stop pumping operations below a predetermined weight. Time clock control of the sludge pumps is another method of obtaining both concentrated sludge and frequent tank feedings. Fig. 28 shows a typical plunger type pump used for pumping raw sludge. By the use of the sampling device seen in this picture the operator of a small plant can observe the character of the sludge at frequent intervals and stop pumping operations when the sludge becomes thin.

2. As with Imhoff tanks, draw digested sludge from heated digesters frequently and in moderate amounts. This assures adequate seed sludge in the tanks at all times. The total alkalinity of the tank sludge (as determined by acid titration) should be maintained above 2000 ppm. if possible. The pH can safely drop to 6.6 or 6.7, although it is possible that the gas production will be somewhat affected. Theoretically a pH range of 7.0 to 7.4 is considered desirable, but this is rarely obtainable in the writer's experience with present-day tanks without lime additions, nor is such a high range necessary for successful operation. If volatile acids are determined, a value under 2000 ppm. should be the aim. This test requires distilling equipment and a titration procedure, so that many operators of small plants will continue to find the pH or total alkalinity test easier to perform and preferable. Table V shows the results of examination of a number of samples of digested sludge from heated digesters serving Connecticut communities.

3. In parallel operation, normally all tanks in service should be fed equal volumes of raw solids. In series operation, all raw sludge goes to the primary units with about 75 per cent of the displaced primary volume taken from the top and the remainder removed at intervals from the bottom to displace the heavier solids. Theoretically the daily addition of raw volatile solids to a digester should not exceed 3 to 5 per cent of the volatile solids already present in the tank. In practice, most operators are compelled to make daily additions based on the raw solids accumulations from the treatment process units. Alkalinity, pH and volatile acid tests, previously mentioned, are operating guides to tank loadings where more than one digester is available.

Sludge should not be allowed to remain in secondary digesters for long periods of time, or it may become too heavy for removal. Occasional recirculation of bottom sludge in secondary tanks, during storage periods or initial filling, will help avoid this condition. The introduction of sludge at the periphery of such tanks aggravates this condition and it is the writer's belief that better results are secured by discharge of primary tank sludge near the tank's center at a point about half the tank depth or greater. The argument that discharge at the tank's center results in removal of some partially digested sludge is more theoretical than actual. The practice of drawing sludge slowly, and in reasonable amounts, is of far greater importance in holding back undigested material.

4. Tank temperatures have been increased in recent years. Some digesters in Connecticut have been operated at sludge temperatures of 95 to 100° F.; in others the winter temperature has been nearer 80 to 85° F. because poor tank insulation, inadequate heating facilities, or other factors, have prevented carrying higher temperatures. Higher temperatures promote digestion of scum and accelerate sludge digestion, both being desirable objectives. (See discussion on this point in "Sewage Treatment" by Imhoff & Fair, John Wiley & Sons, Inc., New York, p. 196.)

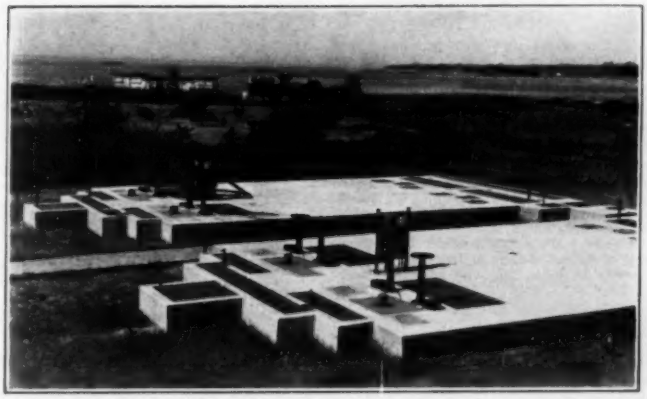


Fig. 33.—Darien, Conn.—Covered Sedimentation Tanks.
(A separate sludge digestion type plant for a modest-sized community.)

5. Sludge soundings were discussed in the article of this series devoted to "Imhoff Tanks." Such soundings or samplings are equally important in the operation of heated digesters. If sufficient sampling taps have been provided by the designer with a convenient sink outlet (described in Part VI) a fairly true inventory of the digester's contents can be obtained by this means. Otherwise some type of depth sampler, such as was described and pictured in the section on "Imhoff Tanks" should be lowered through manholes in the tank cover. Operators should obtain an inventory of the digester's contents at intervals of one to two months. The findings can be tabulated against depth (recording depth of scum, supernatant liquor, and sludge) or plotted on a blueprint of the tank's cross-section. Symons has discussed sludge inventories as performed at Buffalo. Operators would do well to review his procedure[9]. Without periodic soundings, intelligent operation of digesters is not possible; yet many operators fail to make such inventories with the result that scum accumulations may become excessively deep, sludge levels may grow too high, or so much sludge may be drawn from the digester that insufficient remains to maintain the proper balance between digested and fresh solids input.

(Author's Note: The control of scum and the handling of supernatant liquor from established digesters will be discussed separately below.)

Controlling Scum

When is scum of concern in the operation of digesters? First, when it becomes so matted and thick that it retards the escape of gas or overloads stirring equipment. Second, when it slowly but persistently increases in depth, with or without apparent digestion. Sometimes scum accumulations are the result of certain industrial wastes, particularly those of a greasy or fibrous nature. When scum, digested or undigested, continues to accumulate it must eventually be removed or the scum and sludge levels will meet and no supernatant liquor zone will remain. Most of the scum control measures have been discussed in previous articles in this series. Summarized, together with one or two additional controls, they include:

TABLE V

Analyses of Composited Digested Sludges

(Samples from Separate Heated Sludge Digesters in Connecticut)

Sample	Moisture %	Fixed Solids, %	Volatile Solids, %	Alkalinity (Total ppm.)	pH
1	92	46	54	3300	7.1
2	91	65	35	1000	6.7
3	96	40	60	2000	6.9
4	93	50	50	1800	6.8
5	91	49	51	3100	7.1
6	93	50	50	2500	7.0
7	87	68	32	1300	6.8
8	96	45	55	2400	6.9
9	90	46	54	2100	7.0
10	89	56	44	2900	7.0
11	87	59	41	4400	7.2
12	87	62	38	3000	—

1. Use of water spray piping under tank covers.

2. Use of the slow stirring type of mechanical breaker.

3. Hosing with water or supernatant liquor through the cover manholes, with subsequent removal to vacuum filters, sludge drying beds, or lagoons through side wall supernatant overflow pipes.

4. Manual forking out of stringy or matted material from access manholes in the tank cover.

5. Fine screening of raw sewage prior to sedimentation if fibrous wastes entering the sewers are giving trouble. Pre-screening of fibrous wastes at the offending factory is desirable, too, with adequate supervision.

6. Better cover insulation.

7. Resting the digester, where possible.

8. Carrying a lower sludge level may have some effect due to the increased length of travel for gas-buoyed solids to the surface.

It should be emphasized that if the scum in a digester is fairly black, soft, homogeneous, has no offensive odor, and remains reasonably constant in depth, it should be considered a normal condition and need cause no concern.

Handling of Supernatant Overflow Liquor

A digester that is not overloaded and is properly operated will usually produce supernatant liquor of good quality. Analyses of typical digester overflow liquors are given in Table VI. The *total* solids in the average overflow liquor should run 0.5 percent (5,000 ppm.) or under. A total solids content of 0.3 percent or under constitutes good liquor. When the total solids exceed 1 percent, the discharge would be more rightly termed, dilute "sludge."

The *suspended* solids in good overflow liquor will run about 1,000 ppm.; but 2,000 ppm. is more likely to be average for many digesters. When the liquor has more than 3,000 ppm. of suspended solids, it may adversely affect the settling tank effluent if returned to the raw sewage.

For small plants with limited laboratory equipment, a settling test on overflow liquor may be made by the use of a graduated cylinder. The procedure and results to be expected were described in the third article of this series under the heading "Unheated Digesters."

The following suggestions may prove helpful, when either the quality or quantity of digester overflow liquor is causing trouble:

1. Carry as low a sludge level as permissible and still maintain sufficient seed sludge.

2. Be sure scum depths are not excessive —i.e., not more than 3 to 4 feet.

3. Try a lower digester temperature if the tank is a heated unit operated alone or in parallel with other digesters. If the piping arrangement will permit switch to trial series operation if parallel operation has been practiced with difficulty.

4. Draw supernatant more slowly. (See the earlier discussion of Part V.)

5. With floating cover tanks, draw liquor after a period of quiescent settling; never immediately after pumping raw sludge, recirculating or drawing bottom sludge.

6. With fixed cover tanks, decrease the raw sludge pump speed so that the displacement of digester liquor will be at a lower rate.

7. If the tank has a number of supernatant liquor draw-off levels (and all digesters should), sample the entire tank depth frequently to determine the best drawing level.

8. Revise the raw sludge pumping schedule so that more concentrated raw sludge will be discharged to the digesters. This will greatly reduce the disturbance of the digester contents as well as the volume of overflow liquor. Visual observation of the character of the raw sludge and daily records of its volume are operators' "musts."

9. With a fixed position digester overflow, an improvement is often possible at small expense by building a wooden baffle or box around the discharge pipe, extended to a depth shown by experience to yield overflow liquor of good quality.

Safety Precautions

Operators should be familiar with the recommendations in Manual of Practice No. 1 on "Occupational Hazards in the Operation of Sewage Works."[10]

The following items are a brief summation of the most important safe practices:

1. Use a combustible-gas indicator or the soap solution test at regular intervals to check all sludge gas piping and appurtenances for leaks. Leaks, although frequently of a minor nature, are very common in gas systems and if neglected may become serious. The odor of sludge gas cannot always be depended upon to detect its presence.

2. Always keep a digester filled to the overflow level or, if equipped with a floating cover, keep the cover floating. Partially filled digesters constitute a serious explosion hazard.

3. Maintain adequate ventilation in working galleries near sludge pumps, digesters, gas piping and the like.

4. When a digester is being emptied for repairs or inspection, permit no workmen to enter the tank until the atmosphere has been tested for the absence of noxious gases *or oxygen deficiency*. The importance of oxygen deficiency has too frequently been overlooked when entering sumps, pits, etc. In general, allow no smoking or open flames, and guard against sparks during digester emptying operations. All lighting equipment must be of the safety gas-proof type and this applies to extension lights and flashlights. Workmen should enter the tank, *after testing the atmosphere*, with safety belts attached and at least two men on duty at the top. If the emptied digester still contains some scum and sludge, tests for noxious gases and oxygen deficiency should be repeated at intervals.

Use of a non-sparking portable air blower, set up over a manhole in the tank's cover, is recommended. All manhole covers should be off. If noxious gases are present or an oxygen deficiency exists, which has not been corrected by ventilation, workmen should normally be excluded from the tank until a safe working atmosphere is obtained. To quote from the Sewage Works Federation Manual:

"Work that is progressing in flammable gas atmospheres is extremely hazardous and should never be attempted except by those thoroughly familiar with the dangers and fully equipped with the proper protective safety equipment."

Inasmuch as the Federation's Manual lists both the dangers that may be encountered and the proper protective equipment to use, the reader should consult this source for details.

TABLE VI

Analyses of Overflow or Supernatant Liquors

(Composite Samples from Separate Sludge Digestion Tanks in Connecticut)

Sample	Type of Digester	Total Solids (ppm.)	Suspended Solids (ppm.)	Total Alkalinity (ppm.)	pH
1	Heated, floating cover, normal load	4000	2200	2000	6.8
2	Heated, fixed cover, fixed overflow	4200	2700	—	7.0
3	Heated, fixed roof, rectangular	4400	3100	—	7.1
4	Unheated, open top secondary tank	1500	290	2100	7.0
5	Unheated, rectangular secondary tan't	800	100	1600	7.2
6	Unheated primary, some overload	10,000	1300	3900*	7.2*
7	Heated, rectangular	1100	430	1800	6.8
8	Heated, floating cover	3000	—	1800	6.8
9	Heated, primary	1400	190	1200	6.9
10	Heated, primary	7000	5100	2100	7.0

*This tank regularly limed.

PART VII

Lagoons and Lagooning

A review of established methods for the digestion of sewage solids would be incomplete without a consideration of sludge lagooning. The lagooning of digested sludge from Imhoff or separate sludge digestion tanks and, of partially-digested sludge from septic tanks has been successfully practiced in Connecticut and many other states. Lagooning of undigested sludge is not so common. It is discussed in some detail by the 1948 Committee on Sewage Disposal of the American Society of Civil Engineers, and also by Bloodgood in *Water & Sewage Works* for September, 1946 (page 344). The writer has had little personal experience with the digestion of raw sewage solids by lagooning, but in order to present all established methods for sludge digestion he is abstracting here the salient features of lagooning from the above mentioned sources. Certainly as a supplemental or emergency method of sludge digestion, lagooning under some conditions deserves consideration.

When Lagooning Is Indicated

Lagooning of sewage solids is not generally a practice to be advocated but it may prove under favorable conditions to be an economic "out" for both small and large plants. Lagooning has been practiced for years at Indianapolis, more recently at Chicago and up to now at Toronto—to mention three large plants. Lagoons may serve as adjuncts to overloaded separate digesters or overloaded Imhoff tanks and as such are really "secondary open unheated digesters." They are also useful for the disposal of sludge and scum from septic tanks at small plants.

Abstracts from the 1948 A.S.C.E. Report

"There are about 82 sludge lagoons in the United States. When receiving raw solids, a lagoon may be difficult to control in a Northern climate, and may give rise to unpleasant odors, particularly in the late spring, when the sludge temperature begins to rise above 60° F. and the sludge held through the winter starts to decompose.

"When receiving digested solids, a lagoon becomes a storage basin and can be loaded over a period of years and then dried out and cleaned. Apparently odors should be at a minimum when digested sludge is used.

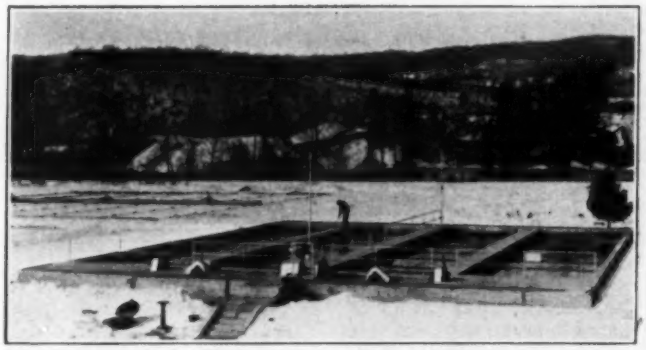


Fig. 34.—Torrington, Conn.—Sedimentation Tanks.

"In the southwestern states, with a monthly air temperature averaging above 60° F., open-air unheated separate digestion or lagooning should prove adaptable and efficient, with proper design for mixing and seeding and withdrawal of supernatant."

The report lists among others the following large cities as using lagoons for receiving digested sludge:

TABLE VII

Cities Lagooning Digested Sludge

City	Estimated Population Served	Lagoon Volume in Cu. Ft. per Capita
Akron	280,000	10.1
Baltimore	811,400	1.36
Chicago, West Side	1,407,800	3.66
Dallas, Texas	294,700	4.73
Decatur, Ill.	65,000	37.5
Fort Wayne, Ind.	130,000	—
Pontiac, Mich.	73,000	10.4
Rockford, Ill.	115,000	0.93
Schenectady, N. Y.	60,000	2.0
Trenton, N. J.	124,700	28.9
Waterloo, Iowa	50,000	6.0
Wichita, Kansas	115,000	0.44

The report states that in the following cities lagoons are used to dispose of undigested sludge:

TABLE VIII

Cities Lagooning Raw Sludge

City	Estimated Population Served	Lagoon Volume in Cu. Ft. per Capita
Indianapolis	402,900	60.1
Rahway, N. J.	80,000	5.4
Houston, Texas:		
North Plant	230,000	6.9
South Plant	165,000	7.2
Sanitary District of Chicago:		
Calumet Plant	294,800	18.0
Southwest Plant	1,127,700	—
North Side Plant	1,020,000	—
Southwest plus North Side Plant	2,147,700	51.2
Toronto, Ont.	—	—

The large populations connected to these plants are of interest. Details of the lagooning operations have not been published for many of these plants except by Bloodgood for Indianapolis. Pertinent remarks from his article in *Water & Sewage Works* follow:

Raw Sludge Lagooning at Indianapolis

"Lagoons have been used for 20 years without creating a nuisance. Although not a satisfactory method for sludge disposal for all installations, lagooning can in many cases meet emergencies. The smallest lagoon now in service is about 300 by 325 feet. The levees are about 12 feet high with a walkway at the top. The sludge is distributed to the lagoons through steel pipes laid three to four feet deep in the levees. No attempt has been made to return supernatant to the sewage plant. If the supernatant flows through several lagoons and finally into one containing practically no sludge, the final overflow will be entirely satisfactory for discharge into the receiving stream. Supernatant or sludge is drawn from one lagoon to another through pipes placed across the levees at about a depth of 3 feet. An underdrain system for lagoons is not necessary for successful operation.

"In starting a lagoon it is desirable to fill it with supernatant or digested sludge to a depth of 3 or 4 feet before any raw solids are added. The addition of sludge goes on for many months (adding sludge a few days at a time and then resting) until it is impossible to add more without the sludge overflowing.

"A 'lay-by' period for 18 months results in a sludge moisture content as low as 75 per cent. During this period a portable pump is used to remove free water which accumulates at the low points in the bed. When the sludge is ready for removal a motor crane with clamshell bucket and caterpillar treads is used.

"In operating lagoons it is necessary to discontinue the addition of raw solids upon the detection of the slightest objectionable odor.

"For digestion only, lagoons can digest at least 6 lb. of solids per year per cu. ft. of capacity. This is equivalent to 0.17 cu. ft. capacity per pound of solids. If the lagoons are used for digestion and also as dewatering beds, a capacity of 0.37 to 0.40 cu. ft. per lb. of raw solids per year is sufficient, providing the air-dried sludge can be removed as rapidly as it is ready for hauling. With the above capacities a supernatant of good quality is possible."

General Summary of Parts I To VII Inclusive

Existing methods for the digestion of sewage solids include: septic tanks, Imhoff tanks, unheated and heated separate sludge digesters, and lagoons as supplemental units.

The selection of a given method for sludge digestion depends on the plant location, the connected population or flow, the character of the raw sewage, the practicability of utilizing the sludge gas, the number and type of operating personnel to be provided, and the funds available for initial construction and plant maintenance.

Septic Tanks

Given a fairly isolated site, these tanks will treat connected populations up to 1500 persons economically, both in first cost and maintenance. When designed and operated in accordance with the suggestions in Part I, septic tanks will produce effluents comparable with plain sedimentation units and the sludge and scum deposited in them can be dried and disposed of without serious nuisance. They require a minimum of operating attention and circumvent the headaches of over-mechanization in small plants. A return to a sensible evaluation of the septic tank is suggested.

Imhoff Tanks

Relatively isolated plant sites are again a requirement. Imhoff tanks best serve connected populations of 500 to 15,000 or 20,000 with a narrower range of 1500 to 5000 offering special advantages. Although regular operating attention is required, unskilled labor generally suffices. Modern design should emphasize higher sludge storage capacities, sufficient depth of tanks, mechanical aids for scum and skimmings removal, and pre-treatment of the raw sewage by screening and grit removal.

Unheated Separate Sludge Digesters

Unheated digesters used alone in northern climates have their field of greatest usefulness between 1500 and 5000 population. In a southern climate they may suitably serve much higher population loadings. Used as secondary units in conjunction with heated digesters they have a wide and varied field of use. Access to scum and multiple decanting levels are pertinent design requirements. With a sludge storage capacity equivalent to that recommended for Imhoff tanks, unheated digesters when used alone will produce comparable sludges. Unheated digesters, although requiring more careful operating attention than Imhoff tanks, afford better means of control of the digestion process.

Heated Separate Sludge Digesters

Heated digesters afford precise control of sludge digestion for large connected populations, can be located in congested areas,

Fig. 35—Hartford, Conn.—Industrial Railway Used for Transporting Sludge Cake.

and permit utilization of a valuable by-product, the sludge gas. The sewage solids must, however, be amenable to digestion and the operating personnel properly qualified. Single units should be avoided, if possible. Positive means for scum control is needed. One aid is the provision of at least four tank cover manholes with one manhole located over the supernatant piping. A variety of satisfactory heating layouts is available. Sludge capacities need liberalizing. Control galleries equipped with sampling sinks and several supernatant draw-offs should be incorporated in the design. An alternate method for supernatant liquor disposal is desirable. Improvements in tank insulation in northern climates are needed. The gas collecting system should be designed *in detail* in accordance with safe practices. Proper liming of new digesters or overloaded digesters will avoid many operating headaches. A detailed procedure, successful for many years, for starting up new tanks has been outlined, together with the major factors in operating established digesters.

Lagoons

Lagoons as secondary digestion units following partial digestion in primary digesters afford an economical method of sludge treatment at plant sites with ample and isolated land areas. The digestion of raw solids in lagoons is attended by additional requirements if nuisance is to be avoided. In many cases lagooning is not practical and in others should be looked upon as a strictly supplemental or emergency method of sludge digestion until one of the other methods can be substituted.

Regardless of the method of sludge digestion selected, satisfactory results are dependent on competent engineering design, qualified and conscientious operating personnel, and cooperative supervising officials. A sewage treatment plant favored with such a combination is sure to perform successfully.

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DETERMINATION OF SUSPENDED SOLIDS IN AERATION TANK LIQUOR

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DETERMINATION of the suspended solids in mixed liquor is an important control test in the operation of an activated sludge plant, as this quantity enables an operator to manage properly the wastage of return sludge. Since this determination is frequently the only truly operational test, as distinguished from performance tests, that requires use of an analytical balance it is desirable that the method selected be a rapid one and entail only the minimum of incidental pencil work records.

In the technique outlined below a simplifying feature introduced which consists in writing all weights directly on the back of the filter paper used, thereby preventing confusion when more than one tank is sampled and obviating the usual intermediate work sheet ruled for source, initial weight, final weight and resulting suspended solids. Filtration through paper has been found preferable over other suggested methods due to its convenience, rapidity of filtration and speed in drying, as contrasted with use of Gooch crucibles or drying directly in a centrifuge tube.

Procedure

Steps in the determination of suspended solids in mixed liquor by means of this method are as follows:

1. Dry a 7 cm. diameter filter paper (Whatman No. 2 or equivalent) in an oven at 103° C. for 15 to 30 minutes. Qualitative grade paper may be used if the operator is satisfied with a filtrate that is not altogether clear.
2. Cool for 5 minutes in a desiccator and weigh to the closest milligram. A counterpoise weighing about the same as an average filter paper conserves time in balancing.
3. Write the tare weight directly on the paper about half an inch from its edge. When about to place the paper in the funnel, also mark the tank number of the sample.

Filter Paper with Weights and Tank Number Written on Under Side

4. Meanwhile have 100 ml. of sample of mixed liquor setting in a graduate for about 5 minutes, in order to settle the sludge partially and facilitate filtration.
5. Place the filter paper in a Buechner funnel. Prevent the sludge from spreading beyond the outer edge of the filter paper by pouring the liquor into a hollow cylinder which is placed in the funnel so as to allow 1 cm. clearance. Press the cylinder snugly on the paper. This cylinder can be padded by inserting it into a bicycle tire inner tube and folding over the end to form a gasket. Pour on a few milliliters of supernatant from the graduate, apply suction and filter the sample. Then remove the paper carefully with a knife so as to retain all sludge deposited.
6. Dry the paper and residue for 15 to 30 minutes at 103° C.
7. Fold the paper in half with sludge side in; cool for about 5 minutes in a desiccator, then weigh. Folding retards gain in weight by absorption of moisture from the air in the balance case and in the desiccator when the drying agent is spent.
8. Mark the final weight on the paper directly above the initial weight. Perform the subtraction on the paper; ten times the gain in weight in milligrams gives the suspended solids in parts per million. This result is recorded in the plant record book and the incidental weights are discarded with the used filter paper.

A typical sheet of filter paper used in the above manner at the Springhill, La., activated sludge plant is shown in the illustration.

This method can readily be made to mesh in with the other analytical duties in the plant laboratory. If adopted as routine, a week's supply of filter papers may be preweighted at one time, thereby permitting direct use without individual preparation each day. The above procedure is applicable to the determination of solids in any plant liquor in which the solids content is flocculated and relatively high; it is not recommended for the average influent or the effluent.

*Louisiana State Dept. of Education.

ESTIMATING FOOD WASTE LOADINGS ON SEWAGE TREATMENT*

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IN a recent paper [1] the author has discussed the probable future of household garbage disposers and, as a result of a survey in Indianapolis, Ind., has offered the prediction that by 1965 about 45 per cent of residences in the study area will be so equipped. Outlined herein is a method of forecasting necessary design data to care for the added loadings involved in handling food wastes in municipal sewage treatment plants.

No function of local government is older than that of garbage and rubbish disposal. Nevertheless, no service of community living has been so universally abused, neglected, and ignored as the disposal of organic wastes.

Household garbage disposal is not so simple. Now, however, a "neat little lever" is available to ease the householder's pain —the kitchen garbage disposer. At the same time it will provide growing relief from the headaches of the garbage collection department. Probably it will never, in our time, become a 100 per cent remedy.

During the past 15 years several articles have been written concerning the effect of garbage disposers on the sewage system. Some emphasize the probable cost effect on sewage treatment. However, sewage treatment takes only one part of the tax dollar. The problem should be examined on a broader base—that is, the over-all effect on the taxpayer. Although disposal of household food wastes to sewers eventually may have some appreciable effect on the cost of sewage treatment, it will at the same time have the effect of reducing the cost of garbage collection and disposal. Thus, it represents one budget item to the sewage plant operator, but two or more items to the municipal housekeeper.

The ensuing statements and discussion are more or less influenced by thinking in terms of the municipal housekeeper. More particularly are they based on the following:

1. No experimental, or pilot plant of appreciable size, known to the writer, has been operated using ground garbage from kitchen disposers.

2. The character of garbage from industrial grinders is not like that from kitchen grinders.

3. Never in this century will all of the dwellings of an average community be equipped with kitchen disposers.

4. Garbage entering the sewage treatment plant from household disposers will have an effect on the treatment process quite different from that where industrial grinders are used and the material discharged directly into digesters.

Quantity and Character of Garbage

During the normal course of living, people produce and discard waste materials, both liquid and solid. As our mode of eating and living changes, so changes the quantity and character of human wastes.

More and more food products are being put up in "throw-away" containers. Some are combustible containers and many are of metal and glass. This situation is increasing the quantity of rubbish discarded per person and may eventually decrease the per capita garbage rate.

The quantity of garbage produced in a community is influenced by the geographical location of the community, the seasons, and the habits and economic status of its inhabitants. For the purpose of estimating the quantity of garbage produced in communities of the East North Central States it is thought that 0.5 lb. per capita per day is conservative. It might be mentioned in passing that although the per capita garbage quantity has remained unchanged over the past 20 or 30 years, the rubbish quantity has increased substantially.

Climatic zones affect both the quantity of refuse produced and the character of garbage. In the South where the growing season is longer, more fruits and vegetables are consumed, thereby producing garbage of higher moisture content during more weeks per year, and thereby raising the average annual moisture content above that usually found in the North.

The moisture content of garbage will vary from about 70 per cent to 80 per cent by weight. Volatile, or combustible content will range from 15 per cent to 27 per cent; ash, or mineral matter is about 3.8 per cent.

Garbage Disposal Services

Garbage collection and disposal is one of the most expensive of municipal services. Moreover, it is the source of more complaints from residents than any other function of the municipal housekeeper.

Whether the disposal method be incineration, reduction, sanitary land fill, hog feeding, or just plain dumping, the collection cost may well be three times the disposal cost. Gross inefficiencies are inherent in the best of collection services, as seen in data from a recent time study of a garbage collection service.

The collection equipment used in the service studied consisted of truck-tractors and trailers. When the trailer was loaded it was unhooked from the truck and an empty trailer was attached. This transfer was made "on the spot," so a minimum of lost time and travel was experienced. In the area studied there were 7,371 dwellings containing 7,946 families. Two collection crews of three men each provided the service during a 10½-day period.

During this period the crews traveled a total of 362.7 miles, and worked 70 hr. and 16 min. Of the total travel, about one-third (120.6 miles) was on actual collection service. Of the total working time, 68 per cent was devoted to actual collection work. The remaining 32 per cent of the time of three men was spent riding from the garage to the collection area, from the collection area with loaded truck and trailer to the disposal point, and from the disposal point back to the collection area or to the garage. Further, the vehicles traveled 139.1 miles while empty.

Although the type of equipment used is not considered sanitary and is now generally out-moded, it did keep the ton-mile cost of collection at a practical minimum. Garbage hauls of 5 miles are not unusual, and in metropolitan areas hauls of 12 to 15 miles are not uncommon.

In Muncie, Ind., a city of 60,000, where the average haul is about 6 miles, it was calculated that if 75 per cent of the garbage were eliminated from the collection and disposal service, the annual saving to this service would be about $24,000. As the Muncie budget item for refuse service is about $90,000 per year, the potential saving is of considerable importance. Therefore, any appraisal of the kitchen garbage disposer should be on the broader basis—as viewed by the municipal housekeeper, and not confined to its probable effect on sewage treatment facilities alone.

Sewage Characteristics

Later in this paper the potential effects of kitchen garbage disposers on sewage treatment facilities are discussed, as applied to Muncie, Ind., a community that has been aptly called "Main Street, U. S. A."

A recent sanitary survey of that city provides the following data on the sewage:

Present population	60,000
Sewage flow (g.c.d.)	200
Suspended solids (p.p.m.)	200
Susp. vol. solids (p.p.m.)	140
5-day B. O. D. (p.p.m.)	130
Total solids (p.p.m.)	1,050
Total vol. solids (p.p.m.)	437

For the undigested sewage sludge the ultimate analysis is as follows:

Component	Dry Solids (%)	Combustible Solids (%
Carbon	45.1	56.5
Hydrogen	6.1	7.6
Oxygen	24.4	30.6
Nitrogen	3.3	4.2
Sulfur	1.0	1.1
Ash	20.1	.....
Total	100.0	100.0

Effect of Disposers on Sewage Treatment Facilities

In the past some very definite conclusions and statements have been published regarding the effect of garbage from kitchen disposers on sewage treatment facilities. Apparently the experience at plants where garbage from industrial grinders is discharged directly to digesters has had a major part in the thinking behind such conclusions. Disposer garbage going through the treatment plant with sewage most certainly will not have the same final effect as industrial grinder garbage going to the digesters direct.

No plant has ever received disposer garbage in any but relatively minute quantities. Only at Indianapolis, Ind., has a sewage plant ever received and taken through the treatment process industrial grinder garbage for any length of time or in appreciable quantity. There, from June through December, 1935, over 15,000 tons of garbage were disposed of through the sewage treatment works. The late Cecil K. Calvert was plant superintendent during that operation and in his report of the experience said, "Sludge production

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was a little higher, perhaps, than usual, but was almost normal."

His report shows that the increase in raw sewage solids due to garbage was 5 per cent total solids and 13 per cent suspended solids. The garbage was from an industrial grinder equipped to produce solids of ¼-in. size and under.

Mr. Calvert also said, "It appears on first thought that garbage should add a very heavy load to that which the sewage plant must treat, but every sewage plant always receives a considerable amount of waste from the domestic preparation of food. Besides juices, any solids fine enough to pass the sink strainger are flushed into the sewer. In any case, the additional load (from household grinders) need cause the sewage plant operator no alarm. . . . After seven months operation, the conclusion reached is that ground garbage offers no serious problem in sewage treatment and such disposition appears to be more economical than methods now in use."

Any calculations of solids loadings—either garbage, or sewage, or both—should be made on a comparable basis of either total solids or suspended solids. Nevertheless, in many discussions of the effect of ground garbage on sewage treatment facilities the total solids of garbage are used whereas only the suspended solids of sewage are considered. At the same time, in calculating sewage sludge quantities, total solids are used. On the basis of past thinking and methods of calculating the net effects, how can anyone arrive at sound conclusions, much less make positive statements as to plant requirements or added treatment costs?

There can be no objection to computations designed to depict only the worst possible condition that could arise due to ground garbage being admitted to sewage plants. However, it is confusing, to say the least, and technically unsound to overlook or ignore the practical aspects of the problem.

Computations made in the past assume that all of the garbage solids will settle out and add that much more to the present plant load. That assumption is definitely erroneous.

It has been established that the household disposer uses from 1 to 2 gal. of water per person per day, equivalent to 2 to 4 gal. of water per pound of wet garbage. In the laboratories of the writer's firm are three types of disposers. Tests were run using three gallons of water per pound of garbage.

Assuming a sewage flow of 100 gcd., it was found that the garbage solids would be as follows:

Series	Total Solids (p.p.m.)	Suspended Solids (p.p.m.)	Per Cent Suspended
A	132	54	41
B	127	51	40
C	125	37	30

Garbage in Series A and B was collected from various fire stations and ground with distilled water. Series C garbage was from a private residence and ground with tap water. Incidentally, raw and filtered samples of Series C were diluted 20 to 1 and incubated for 18 days to determine the oxygen demand. The results were as follows:

	B. O. D. (p.p.m.)		
	5 days	9 days	18 days
Raw	140	160	340
Filtered	130	180	220

It is believed these data are indicative of what may actually take place in a large scale operation.

In view of the above, is it accurate or practical to use total garbage solids in measuring the theoretical effect on sewage treatment in trickling filter and activated sludge plants? Will not a substantial quantity of dissolved garbage organics become mineralized the same as sewage solids, and leave the plant in the effluent?

The similarity between the ultimate analyses of raw garbage and raw sludge, based on the dry solids of each, is shown in the following:

Component	Sludge	Garbage
Carbon (%)	45.2	45.1
Hydrogen (%)	5.6	6.1
Oxygen (%)	31.6	24.4
Nitrogen (%)	2.1	3.3
Sulfur (%)	0.3	1.0
Ash (%)	15.2	20.1
Total (%)	100.0	100.0

If garbage alone having such an analysis entered an activated sludge or trickling filter plant via the influent sewer, would the effluent or final sludge be expected to be materially different than that from the sewage alone?

Ordinarily about ⅔ of the total solids of sewage are in solution and the final sludge about equals the quantity of suspended solids. Now it appears that about ⅓ of the total solids of garbage from kitchen disposers may arrive at the sewage plant in solution. Certainly not much more than ⅓ of the garbage solids will become sludge.

If the average production of garbage is 0.52 lb. per capita per day, equal to 0.13 lb. of dry solids, it does not seem unreasonable to say that the added sludge load due to garbage will be between 0.13 and 0.13/3 lb. (or 0.044 lb.) per person per day. It does seem unreasonable to use the 0.13 lb., as the actual quantity lies somewhere between the two figures.

Sample Calculation

Using factual data obtained in the Muncie survey and information and data discussed above, calculations portraying the possible minimum and maximum sewage plant loadings can be made. It should be noted that only 50 per cent of the dwellings are assumed to have disposers, in accordance with the saturation of sales expected by 1970. Furthermore, the calculations in Table I assume that 95 per cent of the suspended solids of sewage go to digestion, and that, in one case, 100 per cent of the total solids of garbage go to digestion.

Table I is intended to depict the maximum and reasonable minimum loadings. Using average garbage quantities—that is, the average of the total and suspended quantities—gives 13,910 lb. per day of digested sludge, or an increased of 12.6 per cent in dry digested sludge due to garbage. Based on the calculations it is the writer's opinion that the sludge facilities of no sewage treatment plant will have to be enlarged more than one-eighth in the next 20 years due to kitchen garbage disposers.

It will be noted that the foregoing calculations are not truly representative of the conditions. If one approaches the problem from the standpoint of solids entering the sewage plant it will be found that the load is as follows:

Suspended solids only (lb.)	
In sewage	20,000
In garbage (40% susp. sol.)	1,360
Total	21,360
Increase due to garbage (%)	7.8

In this case it has been assumed that 40 per cent of the garbage solids are suspended. If the plant removes 95 per cent of the suspended solids and this goes to digesters, the increase in the digested sludge due to garbage is 7.2 per cent.

TABLE I

Basic Data of Sewage Plant Loading Due to Ground Garbage in City of 60,000

A.	Population		60,000
B.	Suspended sewage solids (lb. dry per day)		19,000
C.	Total garbage solids (lb. dry per day)		3,900
D.	Suspended garbage solids (⅓ of total) (lb. dry per day)		1,300
E.	Total dry solids, B+C (lb. per day)		22,900
F.	Total dry solids, B+D (lb. per day)		20,300
G.	Dry garbage solids, C as % of E		17.0
H.	Dry suspended garbage solids, D as % of F		6.5
I.	Increase in dry solids due to garbage, basis C (%)		20.5
J.	Increase in dry solids due to garbage, basis D (%)		6.9
K.	Volatile solids (lb. per day):	Basis E	Basis F
	Sewage sludge	13,300	13,300
	Garbage	3,120	1,040
	Total	16,420	14,340
L.	Digested sludge (50% volatile reduction) (lb. per day):		
	Basis E		14,690
	Basis F		13,130
M.	Digester sludge, sewage only (lb. per day)		12,350
N.	Increase in dry digested sludge due to garbage (%):		
	Basis E		18.9
	Basis F		6.3

Although it does not appear accurate to use the suspended solids of sewage and the total solids of garbage for measuring the total load, it would probably be inaccurate to use total sewage solids and total garbage solids. For instance, the total solids of the above sewage was 1,040 p.p.m. If 400 p.p.m. were contributed by the city water, the sewage would contain 640 p.p.m., or 64,000 lb. per day as compared with 20,000 lb. used in the earlier calculations. In this case, the total garbage solids would be 5¾ per cent of the total load.

Conclusions

In appraising the economics of the kitchen garbage disposer one should not limit the considerations to the probable effects on sewage treatment, but should broaden the scope to include the interests of the municipal housekeeper as well as the householder.

When the householder deposits garbage in the kitchen disposer you may be sure it will be nearly pure garbage substance. Only by accident will it contain other materials and they will be beyond recognition when received at the sewage plant.

Water transportation is famous for its relative cheapness. What could be less expensive than water carriage of ground garbage by gravity, particularly when it has no appreciable effect on the hydraulics of the carrying system. Why not utilize the sewer system to transport the garbage of a community?

If the use of garbage disposers follows the sales pattern of most other household appliances, it will be more than 20 years before half the dwellings in the average community will be so equipped. When and if half the dwellings of a community are equipped with disposers, the sludge load at the sewage plant will not be increased by as much as 20 per cent. It will more likely be in the neighborhood of 10 per cent.

Reference

1. Owen, Mark B., "The Future of Home Garbage Grinders." *Water and Sewage Works*, 96, 3, 137 (May, 1949).

LIMITS FOR TOXIC WASTES IN SEWAGE TREATMENT*

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AN examination of the recent literature reveals a large number of articles describing the objectionable effects of various industrial wastes on sewage treatment. The factual evidence from these reports shows that these wastes have caused various troubles, from "excessive foaming" or "retarded digestion of sludge" to a complete breakdown of treatment plant facilities.

It is apparent that the deleterious effects of any industrial waste vary inversely with the dilution afforded by the sewage. Thus, the wastes from a certain industry in a small community might disrupt the treatment plant, whereas its effect in the sewage of a large city would be inconsequential.

Effects of Toxic Wastes

The objectionable effects of an industrial waste may be due to one or more of its various constituents. As an illustration, in the manufacture of mouton fur the following substances may cause trouble in treatment:

1. Grease and excess alkali from the scouring of the skins clog the sewers and retard biological treatment.
2. Heavy suspended solids both from the washing and the tanning overload primary treatment.
3. Toxic chromium from the mineral tan prevents digestion of sludge.
4. Large quantities of organic material having an excessively high oxygen demand overload oxidation processes.

Other wastes have their own characteristic effects. Tanneries, breweries, canneries, slaughter houses, textiles, rubber, metallurgical wastes, and numerous others, have different effects on sewage treatment.

Chromium salts, usually reported in the form of metallic chromium, have different effects on different units of a sewage treatment plant. The chromium is in the trivalent form in spent chrome alum in the wastes discharged from a tannery using a mineral tan. Chromium in this form will precipitate almost quantitatively in an alkaline solution such as sewage, and will be removed as sludge to digestion tanks, where digestion will be retarded or practically stopped. If secondary treatment is used there will probably be very little trouble biologically. On the other hand, if the chromium compounds are discharged from a plating establishment or from anodyzing of aluminum, the chromium is chiefly in the hexavalent form. Chromium cannot be precipitated under ordinary conditions in this form. Therefore, the effect on sludge digestion is very much less. However, in the hexavalent form the chromium is much more toxic, and when present in sufficient quantities will kill the organisms in filters or in activated sludge. The tolerance concentration is controversial. It has been reported to the writer that quantities up to 25 p.p.m. can be handled continuously. Edwards found that shock loads of about 40 p.p.m. slowed up nitrification and caused deterioration in the appearance of activated sludge effluent. Information is still lacking as to the quantity of chromium which is permissible in sewage under the following variable conditions:

1. Type of chromium, trivalent or hexavalent.
2. Type of sewage treatment, such as primary and secondary.
3. Continuous flow versus shock loads over a period of a few hours.

Copper is a toxic substance easier to evaluate. As reported by Mohlman an excess of 1 p.p.m. has caused trouble.

Acid-iron wastes have caused trouble at Worcester, Fostoria, and in many other places.

Daily, weekly or monthly analyses have usually been reported. The question arises as to whether or not the trouble was caused by intermittent discharges of pickling liquors high in iron or acid content, or by a continuous discharge of wastes containing much smaller quantities of iron and acid. Zinc has been reported as detrimental to sludge digestion at Fostoria, Ohio.

Cyanides of 5 p.p.m. discharged continuously have an inhibiting effect on activated sludge treatment. Doses of 20 p.p.m. are reported as having an immediate effect on activated sludge, but after removal of the cyanide, the sludge recovers. Siebert reports that as low as 1 p.p.m. is toxic to biological activities. On the other hand, filtration of much higher concentrations of cyanide, through sand or coke breeze, has been suggested as a method of treatment.

From another point of view cyanides should not be permitted in sewage because of the slight possibility of acid wastes being present at the same time and therefore possible liberation of hydrocyanic acid.

Brewery wastes have interfered with sewage treatment at Jeanette, Pennsylvania. It was found during a recent investigation that the B.O.D. population-equivalent of the waste from a single brewery was greater than the population of the entire city.

Rubber wastes at Akron so overloaded the primary treatment units that the sewage plant reached its designed capacity long before the estimated time.

Substances such as acids, alkalies, silt, plastics, and grease, which cause localized troubles in a sewer, may also cause serious results at the sewage treatment plant.

Soluble cutting oils, while affecting treatment to some degree, are objectionable in that they pass through tanks unchanged and cause marked objectionable effect on the appearance of the receiving stream.

Control of Toxic Wastes

The writer takes the view that industrial wastes should be admitted to municipal sewer systems to the extent that they do not cause breakdown of the collection or treatment facilities either physically or biologically, or so overload the various units that the effluent is impaired to an objectionable degree. In other words, the presence of industrial wastes may cause temporary overloading and accompanying operational vexations, but pollution abatement is nearer being solved and the public better served by treatment of all wastes possible with the sewage in one plant, under the supervision of competent operators.

Whenever the proportion of wastes becomes so great that the sewage treatment plant becomes a wastes treatment plant, it is necessary for industry either to remove its wastes or to pretreat them to an acceptable degree. New sewage treatment plants may be designed to handle the industrial wastes of the municipality if their character and quantity can be predicted.

It is difficult but necessary that certain limitations be placed on the quantity of objectionable or toxic substances that may be present in sewage as received at the treatment plant. Such limits have been proposed by the Allegheny County Sanitary Authority. Table I has been taken from the Authority's recent report "Proposed Collection and Treatment of Municipal Sewage and Industrial Wastes."

It is the writer's opinion that if these concentration limits are met there will be no difficulty in treatment by the usual sewage treatment processes. In fact, it is probable that these limits can be exceeded manifold for short periods without any harmful effect.

A committee is needed to establish maximum limits of objectionable constituents of industrial wastes that are proposed to be treated with municipal sewage.

TABLE I

Concentration Limits for Toxic and Deleterious Wastes in Composite Sewage of Treatment Plant Influent*

Names of Items	Primary Treatment		Secondary Treatment
	No Sludge Digestion	Sludge Digestion	
pH index	5.0	6.5	6.5
Total iron (p.p.m.)	5.0	5.0	5.0
Copper (p.p.m.)	3.0	1.0	1.0
Chromium (p.p.m.)	5.0	5.0	3.0
Cyanide (p.p.m.)	2.0	2.0	2.0
Oils—mineral	Should be excluded by municipal ordinances.		
Oils—soluble	Removed to maximum practicable extent before discharge.		
Combustibles, etc.	Should be excluded by municipal ordinances.		
Free mineral acids	Should be neutralized at source.		
Acetylene generation sludge	Should be excluded by municipal ordinances.		

*Page 22, "Report—Proposed Collection and Treatment of Municipal Sewage and Industrial Wastes," Allegheny County Sanitary Authority (January, 1948).

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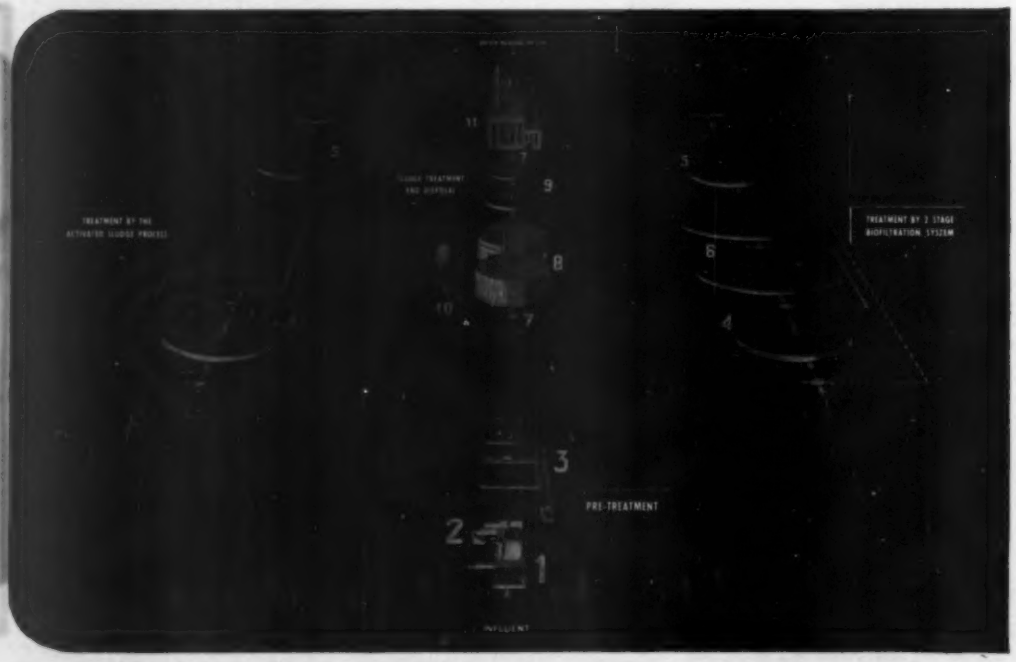
* The Dorr Clarigester
(clarification and digestion)
* The Currie Clareator
(aeration and clarification)
* The Dorrco Vacuator
(for grit, scum and solids removal)

* Alternative or combination units not shown on composite drawing.



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RESEARCH ENGINEERING DORR EQUIPMENT

FORCED CIRCULATION HOT WATER HEAT EXCHANGERS FOR DIGESTION TANK HEATING

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IN RECENT years considerable attention has been given to heating of sludge digestion tanks by means of heat exchange apparatus located externally with respect to the tanks. This development has been a natural result of difficulties with the conventional fixed interior heating coils. The major difficulty encountered with the fixed interior heating coils has been constantly decreasing heat transmission efficiency due to sludge caking and the resultant necessity to dewater tanks for cleaning, thus interrupting operations and in some instances involving considerable labor costs.

Various methods of external heating of digesters have been described in sewage works literature and include the following:

a) Addition of steam to raw sludge.
b) Contact heating of sludge in separate heating tanks or in the digesters themselves in which the sludge is brought into direct contact with intensely hot combustion products.
c) Forced circulation type hot water heat exchangers in which the sludge to be heated is circulated through pipes immersed in a hot water bath.
d) Forced circulation type hot water heat exchangers through which both the hot water providing the heat and the sludge to be heated are circulated by pumping and travel through the heat exchanger in opposite directions.

Of the various methods of external digester heating the forced circulation type hot water heat exchangers have found the widest application. A number of installations have been completed and a considerable number are projected.

In view of the number of such installations which are, or may soon be, in operation, it is the purpose of this article to set forth briefly some fundamental considerations of the theory and practical use of hot water heat exchangers with the thought that such information may be of value to engineers and plant operators in securing and making available to the sanitary engineering profession, operating data on heat exchanger operation.

Equipment Available

Illustrations of some commercial types of heat exchangers which are available are shown in Figs. 1 to 4 incl.

Fig. 1 shows a hot water bath type combination heater and exchanger. The left hand side of the apparatus comprises gas and oil firing units arranged with fire tube flues to heat the contained water bath which transmits heat to the sludge. Return bends on the sludge tube nest are seen at the right hand side of the apparatus. The heat transmission takes place through the walls of the horizontal sludge tubes as the sludge is recirculated therein by means of an external pump. Return bends on the sludge tubes are also located at the rear of the apparatus. All of the return bends are removable to allow straight through cleaning of the sludge tubes. In addition, the sludge tubes can be completely removed for cleaning. The four pipe connections visible at the right comprise two sludge inlets and two sludge outlets. At the rear of the unit may be seen hot water connections to the water bath from an engine cooling system. The controls for the unit provide for automatic heating of the water bath by the firing units when insufficient heat is available from the circulating hot water from the engine cooling system. The exhaust fan at the upper left provides for control of air for combustion and for exhausting of products of combustion of the firing units. The butterfly valve at the fan suction allows withdrawal of air from the room or chamber in which the apparatus is located. Vented hot water expansion tank is seen behind the exhaust fan.

Therefore, the unit shown in Fig. 1 can operate as a stationary water bath type of exchanger with only thermal circulation of the hot water bath and the sludge in motion through the sludge tubes or it can operate with forced circulation of the hot water as well. For the unit shown, the hot water circulation would be caused by a remotely located engine jacket water pump and thus provide for heat recovery from the operation of a diesel engine or gas engine or dual fuel engine.

Fig. 2 shows a similar type unit with single sludge inlet and outlet connection in front and a hot water circulating pump on top. The hot water circulating pump provides for circulating the hot water bath through a building heating system. During seasons when building heat is not required the circulating pump is inoperative and thermal circulation of the water bath around the sludge tubes is made available by opening of an interior thermal circulating valve. The firing units automatically supply heat to maintain the water bath temperature on the fire tube side between a predetermined upper and lower limit. For all practical purposes of calculation, the water bath on the sludge tube side can be considered to be maintained at a constant average temperature.

Fig. 3 shows front and rear views of a forced circulation counter current flow type hot water heat exchanger. Sludge and hot water connections are on the front of the unit. The hot water enters the exchanger at the vertical connection at the upper right and leaves at the side outlet connection at the lower left. The sludge to be heated enters the exchanger at the front connection at the lower left and leaves the exchanger at the front connection at the upper right.

The apparatus comprises essentially a nest of circular tubes and shells. Each tube is concentric with its shell. The sludge travels through the tubes and the hot water travels through the annular space between tube and shell. Baffled manifolds are provided for sludge and water at the front end of the

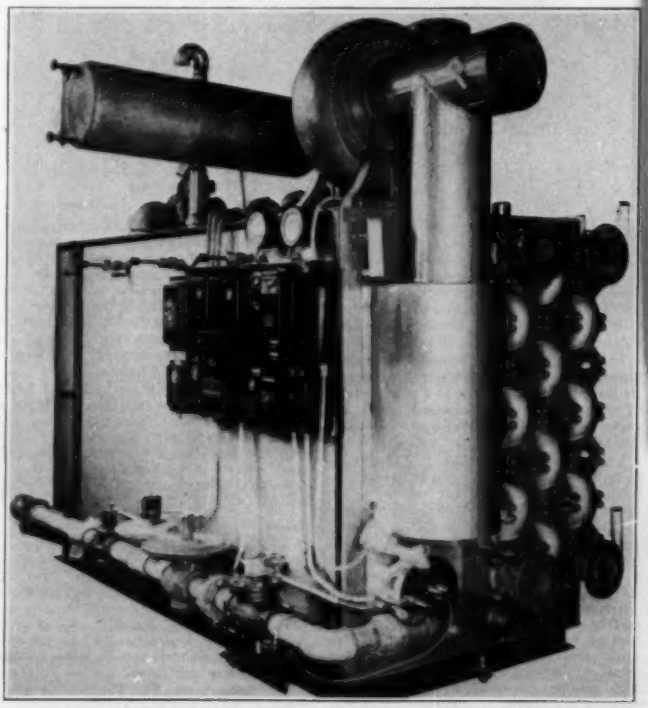


Fig. 1. P.F.T. Hot Water Bath Type Heater and Heat Exchanger
(With twin sludge inlet and outlet connections in front and connections for circulating engine cooling water in rear.)

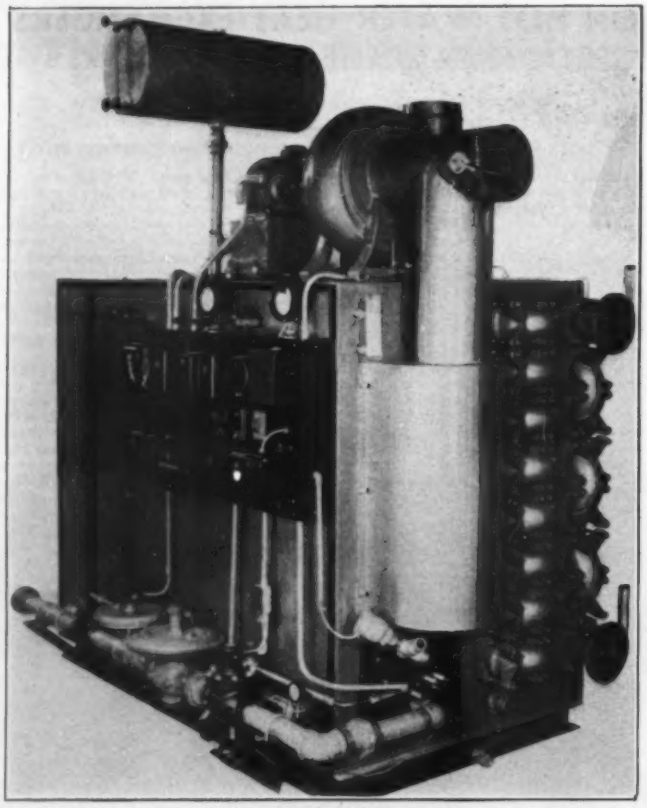


Fig. 2. P.F.T. Hot Water Bath Type Heater and Heat Exchanger
(With single sludge inlet and outlet connections in front and circulating hot water pump on top.)

apparatus and integrated with their respective inlet and outlet connections.

Fig. 3 (lower half) shows the rear view of the apparatus with insulated cover removed and one of the return bends removed. The apparatus is so arranged that shells and tubes can be completely removed for cleaning.

The sludge to be heated is pumped through the unit by means of an external sludge pump. Hot water is also circulated by pumping. Heat is supplied to the hot water by an external boiler unit or from engine jackets and exhaust gases.

The units shown in Figs. 1, 2, and 3 are designed to eliminate the possibility of contamination of circulating hot water or water bath by the circulating sludge.

Fig. 4 (right) illustrates a counter-current flow type spiral heat exchanger with front door opened as if for cleaning. Fig. 4 (left) shows the same unit with the door closed and ready for operation. These units differ from those shown in Figs. 1, 2, and 3 in that no pipes or tubes are used for the heating surface. The heating surface comprises two plates rolled up to form concentric spirals. The sludge and hot water flow counter currently in the two spaces between the plates.

The sludge enters the unit at the connection shown at the top to the right of the center and leaves the unit through a connection at the rear center. The hot water enters the unit at the rear center and leaves at the connection at the top to the left of the center. Sludge is pumped through the unit by means of an external pump as is the hot water. Heat is supplied to the hot water by means of an external boiler, or if heat recovery from engine cooling water is desired, then heat is supplied from engine jackets and exhaust gases.

All of the units shown in Fig. 3 and 4 are available up to capacities as high as 1,500,000 Btu. per hour and higher and water bath type units are available up to 1,100,000 Btu. per hour. All are installed on the basis of recirculating a portion of digester contents through the units continuously.

Theory

In Fig. 5 is shown the temperature and direction of flow diagram for the counter current forced circulation type heat exchanger through which both the hot water and sludge are in motion and flow in opposite directions on opposite sides of metal barriers. The hot water enters the heat exchanger at temperature T_1, gives up heat to the sludge and leaves the exchanger at lower temperature T_2. The sludge enters the heat exchanger at lower temperature T_4, absorbs heat and leaves the exchanger at higher temperature T_3.

In Fig. 6 is shown the temperature and direction of flow diagram for the water bath type of heat exchanger in which the hot water is stationary except for thermal circulation and is automatically maintained at an average temperature and surrounds the metallic pipes through which the sludge to be heated is circulated. The sludge flow is from right to left. The sludge enters the exchanger at cold temperature T_4 and leaves the exchanger at heated temperature T_3.

In the heat exchanger apparatus, the heat transmission from the hot water to the sludge takes place through the metallic barrier separating them chiefly by convection and conduction. The rate of heat flow through the metallic barrier separating the two fluids will depend upon—

1) The contact area available for the transfer of heat

2) The difference in temperature between the hot water and the sludge

3) The overall conductance of the metal barrier, films and deposits

Each of the three above factors directly affects the total rate of heat transfer which may be formulated as follows:

$$H = U \times A \times T_m \qquad \text{(Eq. 1)}$$

where
H = Total rate of heat flow in Btu. per hr.
U = Overall rate of heat transfer for the entire apparatus or overall conductance in Btu. per hr. per sq. ft. per deg. F.
A = Surface area available for heat transfer in sq. ft.
T_m = Mean effective temperature difference between the hot water and the sludge in deg. F.

Fig. 7 shows the effect on the temperature gradient of films, metal, corrosion scale, and deposits while transferring heat from the hot water to the sludge through a metal barrier. The overall conductance U, of the metal barrier including metal, films, scale, and deposits is formulated as follows:

$$U = \frac{1}{\frac{t}{K} + \frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3} + \frac{1}{k_4}} \qquad \text{(Eq. 2)}$$

where
K = Conductivity of the metal in Btu. per hr. per sq. ft. per deg. F. per in. thickness of metal.
t = Thickness of metal wall in in.
k_1 k_2 k_3 k_4 = Conductances of the surface films and corrosion scales or deposits expressed in Btu. per hr. per sq. ft. per deg. F. When a scale or deposit is absent its resistance factor such as $\frac{1}{k_4}$ becomes zero.

The conductance of scale deposits and films can be combined into a term called U_k or the overall film conductance and expressed in Btu. per hr. per sq. ft. of contact surface per deg. F.

$$U_k = \frac{1}{\frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3} + \frac{1}{k_4}} \qquad \text{(Eq. 3)}$$

Equation 2 therefore can be written as follows:

$$U = \frac{1}{\frac{t}{K} + \frac{1}{U_k}} \qquad \text{(Eq. 4)}$$

Otherwise expressed, this means that the overall conductance U of the contact surface separating the hot water and the sludge depends not only upon the kind of metal and the thickness of it but also upon the film, scale and deposit conductances.

The film scale and deposit conductances are a function of their nature and thickness which in turn are a function of the degree of turbulence of the flow of the two fluids under consideration, and their temperature differences.

The greater the turbulence of the flow the greater is the amount of heat convected to

or from the heating surface because many of the fluid particles with component velocities toward the heating surface break through the surface film and carry heat to or from the separating barrier. In addition, relatively high velocities tend to minimize deposition and exert a scouring effect on scales and deposits.

It follows for the type of apparatus under consideration that the detrimental sludge film effects, common to digestion tank coils, are lessened at proper sludge velocities, and higher hot water temperatures are permitted than would be allowable with the conventional interior heating coils. On the other side of the ledger with respect to high velocities is the consideration of head loss through the apparatus.

Thus the overall co-efficient of heat transmission U for the heat exchanger apparatus is also affected by the velocities of flow of the hot water and the sludge.

Experience with heating coils in digesters indicates that the metal resistance t/K is slight and has been neglected in computation since it has been overshadowed by the sludge film resistance. The writer believes, however, that the effect of metal resistance will assume somewhat greater importance in external heat exchanger applications because of structural necessity for thicker metal barriers and deposition and film effects will be lessened by turbulent flows through heat exchange apparatus.

Table I indicates the thermal conductivities of some metals and alloys such as might be used in heat exchangers.

In the choice of metal and metal thickness for heat exchangers, due thought should be given to corrosion and abraison resistance, structural characteristics and conductivity in relation to sludge and water temperatures involved. The likelihood of some metals forming insoluble corrosion products is also of importance.

Measurement of Performance

To evaluate the performance of a heat exchanger, a satisfactory unit of measurement is the determination by test of the overall co-efficient of heat transmission U for the apparatus as a whole under a particular set of conditions.

Overall Co-Efficient of Heat Transmission

The total heat transmitted by the entire heat exchanger apparatus per unit of time can be expressed as shown in Equation

Table I

CONDUCTIVITY OF METALS

(For Temperatures of 32° F. to 212° F.)

Metal	Conductivity Btu per hr. per sq. ft. per deg. F. per in. of thickness
Wrought Iron	370
Mild Steel (S.A.E. 1020)	450
Nickel	420
Red Brass (85-15)	1100
Silicon Bronze	225
Ingot Iron	470
Monel	180
Stainless Steel (types 304, 316, 321)	105
Aluminum (2s)	1570
Pure Copper	2640

No. 1, where U is considered to be the overall co-efficient of heat transmission for the entire heat exchanger apparatus and is expressed in Btu. per hr. per sq. ft. of exchanger heating surface per deg. Fahrenheit.

The area of contact surface can be obtained from the equipment manufacturer or measured and computed thus providing a value for "A" in Equation No. 1. For curved contact areas of ordinary thickness

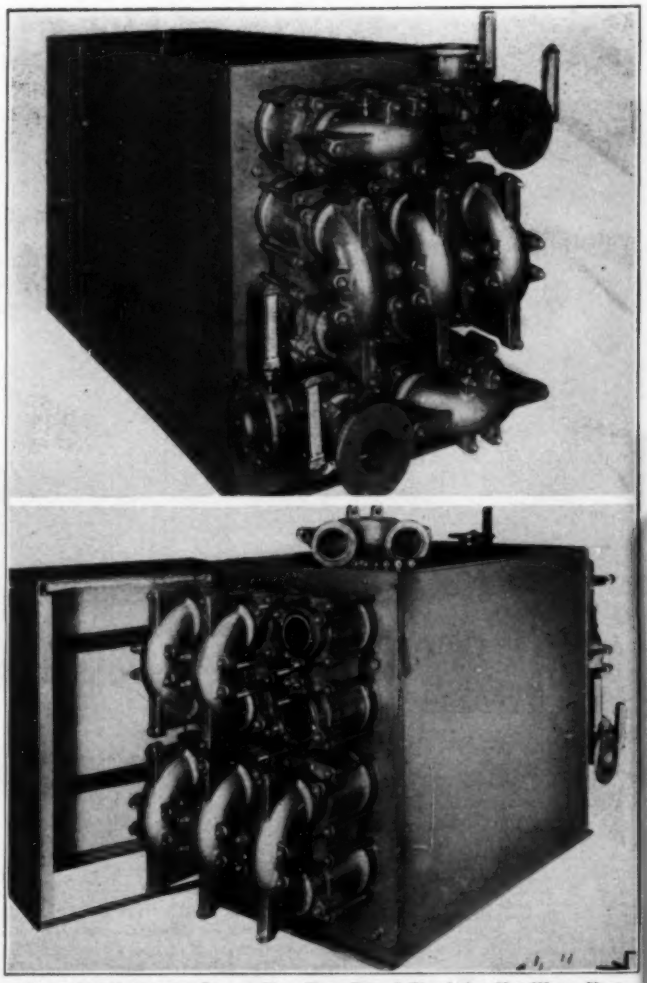


Fig. 3. P.F.T. Counter Current Flow Type Forced Circulation Hot Water Heat Exchanger

(Top—Front View. Bottom—Rear view with casing removed and one elbow removed ready for cleaning.)

the average area of water and sludge contact surfaces provides sufficient accuracy.

Referring to Fig. 5 the value for H in Equation No. 1 can be obtained as follows:

$$H = (T_3 - T_4) \times W_s \times C_s \qquad \text{(Eq. 5)}$$

where

T_3 = Sludge outlet temperature in °F.
T_4 = Sludge inlet temperature in °F.
W_s = Pounds of sludge flowing per hour
C_s = Mean specific heat of sludge (usually taken as 1.0)

If there are no external losses, the heat absorbed by the sludge should equal the heat given up by the hot water.

Therefore,

$$H = (T_1 - T_2) \times W_w \times C_w \qquad \text{(Eq. 6)}$$

where

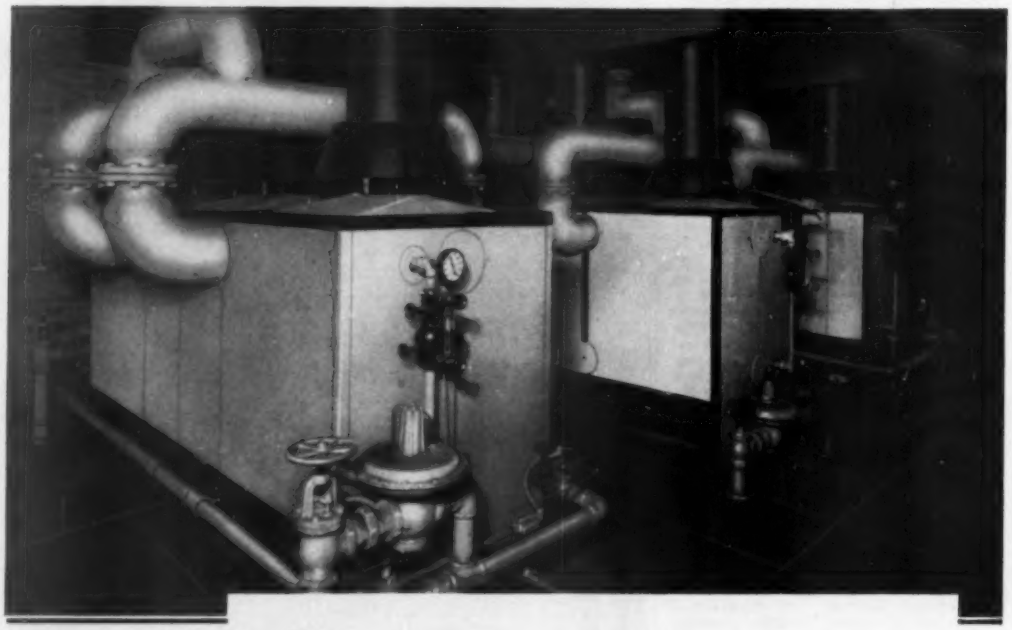
T_1 = Hot water inlet temperature
T_2 = Hot water outlet temperature
W_w = Pounds of water flowing per hour
C_w = Specific heat of water (taken as 1.0)

Under actual test conditions, the heat given up by the hot water is always somewhat greater than that absorbed by the sludge and the difference represents radiation loss. To compute the value of the overall co-efficient of heat transmission the amount of heat calculated by Equation No. 5 should be used since there is usually a small amount of radiation loss.

It will be noted from Fig. 5 and 6 that the variation in temperature of the sludge while traversing the heat exchanger is not a straight line so that the use of an arithmetic mean temperature difference for the value of T_m would not be exact. Commonly accepted procedures are to use the arithmetic mean temperature difference when T_1 and T_3 are close together and the logarithmic mean when T_1 and T_3 are far apart. For all practical applications of hot

(*Continued on page* R-178)

For trouble-free heating



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AMERICAN GAS BOILER CAPACITIES WITH SEWAGE DISPOSAL GAS

BOILER NO.		OUTPUT PER HOUR			INPUT PER HOUR		BOILER SPACE		
Steam	Water	BTU per Hour	Sq. Ft. Steam A.G.A. Rating	Sq. Ft. Water A.G.A. Rating	BTU per Hour	Cu. Ft. 700 BTU Sludge Gas	Over-all Hgt. xx	Floor Space Width	Floor Space Depth
	1-GA-4E	31,500		210	39,375	56	40½"	16"	19¼"
	1-GA-5E	42,000		280	52,500	75	40½	16	22¼
	1-GA-6E	52,500		350	65,600	94	40½	16	25¼
	2-GA-4E	63,000		420	78,750	113	54⅝	16	19¼
	2-GA-5E	84,000		560	105,000	150	54⅝	16	22¼
	2-GA-6E	105,000		700	131,250	188	55½	16	25¼
	2-GA-7E	126,000		840	157,500	225	55½	16	28¼
	4-GA-8E	147,000		980	183,750	263	54	16	37¼
	4-GA-9E	168,000		1,120	210,000	300	54½	16	40¼
	4-GA-11E	210,000		1,400	262,500	375	54⅝	16	46¼
0-GS-4E		61,200	255		76,500	109	52¼	16	33¾
0-GS-5E		81,600	340		102,000	146	53	16	37¾
0-GS-6E		102,000	425		127,500	182	52¼	16	41¾
	1-GW-4	144,000	600	960	180,000	258	57⅝	19	25
1-GS-4	1-GW-5	192,000	800	1,280	240,000	343	59¾	23	25
1-GS-5	1-GW-6	240,000	1,000	1,600	300,000	429	60¾	27	25
1-GS-6	1-GW-7	288,000	1,200	1,920	360,000	517	62⅝	31	25
1-GS-7	1-GW-8	336,000	1,400	2,240	420,000	600	63¼	35	25
1-GS-8	1-GW-9	384,000	1,600	2,560	480,000	686	65	39	25
1-GS-9	1-GW-10	432,000	1,800	2,880	540,000	771	65⅝	43	25
1-GS-10		480,000	2,000	3,200	600,000	857	74	27	41½
4-GS-6	4-GW-6	576,000	2,400	3,840	720,000	1029	75	31	41½
4-GS-7	4-GW-7	672,000	2,800	4,480	840,000	1200	77	35	41½
4-GS-8	4-GW-8	768,000	3,200	5,120	960,000	1372	77⅝	39	41½
4-GS-9	4-GW-9	864,000	3,600	5,760	1,080,000	1573	79½	43	41½
4-GS-10	4-GW-10	960,000	4,000	6,400	1,200,000	1715	80	47	41½
4-GS-11	4-GW-11	1,152,000	4,800	7,680	1,440,000	2060	75	27	41½
4-GS-13	4-GW-13	1,344,000	5,600	8,960	1,680,000	2400	77	31	41½
4-GS-15	4-GW-15	1,536,000	6,400	10,240	1,920,000	2740	77⅝	35	41½
4-GS-17	4-GW-17	1,728,000	7,200	11,520	2,160,000	3086	79½	39	41½
4-GS-19	4-GW-19	1,920,000	8,000	12,800	2,400,000	3425	80	43	41½
4-GS-21	4-GW-21	2,016,000	8,400	13,440	2,520,000	3600	77	47	41½
4-GS-22	4-GW-22	2,304,000	9,600	15,360	2,880,000	4120	77⅝	27	41½
4-GS-25	4-GW-25	2,592,000	10,800	17,280	3,240,000	4625	79½	31	41½
4-GS-28	4-GW-28	2,880,000	12,000	19,200	3,600,000	5145	80	35	41½
4-GS-31	4-GW-31	3,072,000	12,800	20,480	3,840,000	5480	77⅝	39	41½
4-GS-33	4-GW-33	3,456,000	14,400	23,040	4,320,000	6165	79½	43	41½
4-GS-37	4-GW-37	3,840,000	16,000	25,600	4,800,000	6850	80	47	41½
4-GS-41	4-GW-41						153⅝	27	41½
							169⅝	31	41½
							185¾	35	41½

xx To top of Draft Hood

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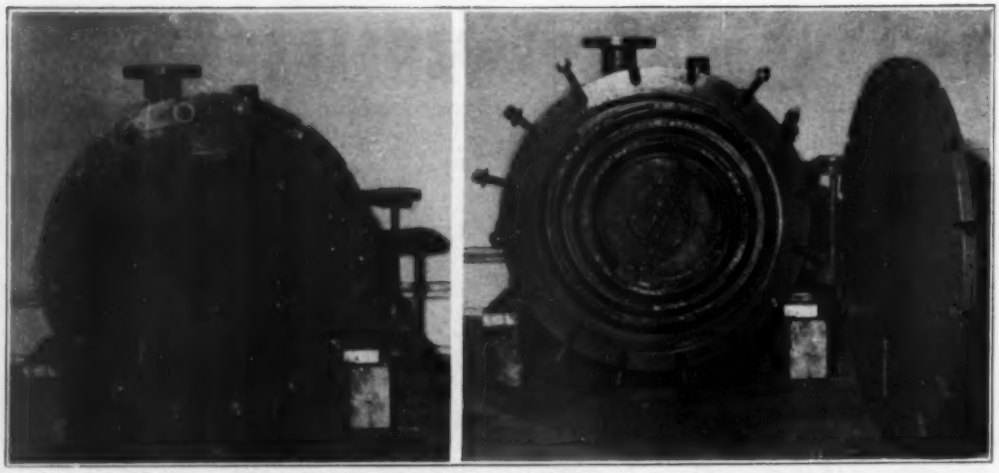

Fig. 4. Dorr Co. Counter Current Flow Type Spiral Heat Exchanger
(Left—With front door closed. Right—With front door open, showing interior.)

(*Continued from page* R-175)

water heat exchangers for sludge heating the arithmetic mean temperature difference is adequate.

It can be seen from Fig. 5 and 6 that T_a equals the temperature of entering hot water minus temperature of heated sludge leaving the exchanger or

$$T_a = T_1 - T_3 \qquad \text{(Eq. 7)}$$

T_b equals temperature of cooled water leaving the heat exchanger minus temperature of cold sludge entering the heat exchanger or

$$T_b = T_2 - T_4 \qquad \text{(Eq. 8)}$$

The arithmetic mean temperature difference is

$$T_m = \frac{T_a + T_b}{2} \qquad \text{(Eq. 9)}$$

The logarithmtic means temperature difference is

$$T_m = \frac{T_a - T_b}{\text{Log}_e \frac{T_a}{T_b}} \qquad \text{(Eq. 10)}$$

The logarithmic mean temperature difference provides extreme accuracy which is not warranted when accuracy of observations of this type is considered. If desired, however, it is easily computed by use of a table of natural logarithms.

Thus with all values known, except U, Equation 1 is easily solved for U.

Therefore, if a new or just cleaned heat exchanger is tested with measured rates of sludge and water flow and entrance and exit temperature of both hot water and sludge are read, the overall co-efficient of heat transmission for the exchanger may be computed. After a period of operation the test can be made again at the same rates of sludge and hot water flow and the effect of films and scale can be evaluated. If flow rates and temperatures are varied, curves of heat transmission for various flows and temperatures can be obtained for study to determine optimum efficiency conditions.

Example

Assume that a performance test was run on a heat exchange apparatus similar to those shown in Fig. 3 and 4 and the following average for test run data was obtained:

Hot Water Flow	62 gpm.	
Sludge Flow	75 gpm.	
Hot Water Inlet	Temperature (T_1)	150° F.
Hot Water Outlet	Temperature (T_2)	136° F.
Sludge Inlet	Temperature (T_3)	89° F.
Sludge Outlet	Temperature (T_4)	100° F.

Heating Contact Surface ..... 83.2 sq. ft.

Heat Absorbed by Sludge =

75 gpm. × 8.34 lb./gal. × 1.03* × 60 min./hr. × (100 − 89)°F. × 1 btu./lb./°F. = 425,000 btu./hr.

*Specific Gravity of Sludge

Heat Given up by Hot Water =

62 gpm. × 8.34 lb./gal. × 60 min./hr. × (150 − 136)°F. × 1 btu./lb./°F. = 434,000 btu./hr.

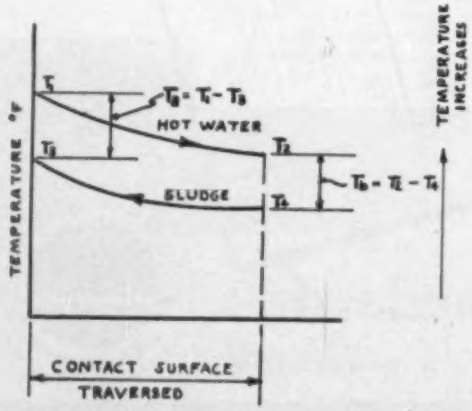

Fig. 5. Counter Current Flow Type of Heat Exchanger—Direction of Flow and Temperature Diagram.

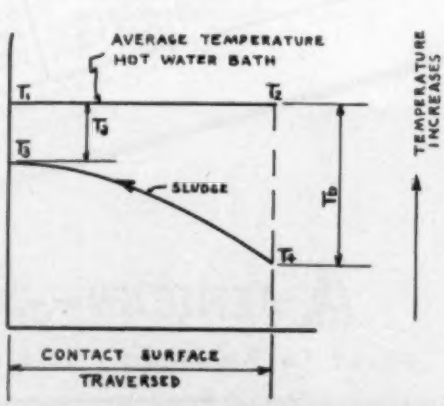

Fig. 6. Water Bath Type of Heat Exchanger—Direction of Flow and Temperature Diagram.

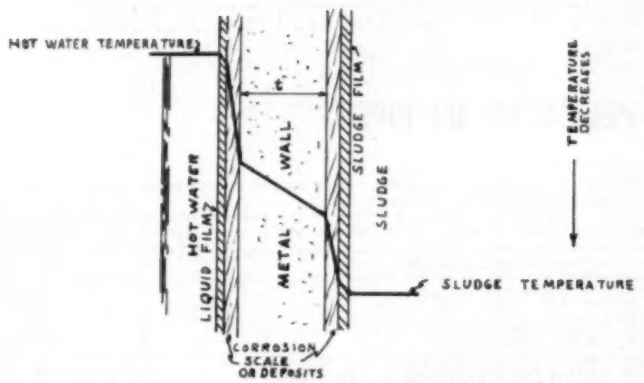

Fig. 7. Temperature Gradient Through Heat Transmitting Surface.

Radiation Loss =
$(434{,}000 - 425{,}000) = 9{,}000$ Btu. per hr. $\quad 9{,}000/425{,}000 = 2.1\%$ Radiation Loss

$T_a = 150°F - 100°F = 50°F$
$T_b = 136°F - 89°F = 47°F$

Mean Temp. Diff. $T_m = \dfrac{50 + 47}{2} = 48.5°F$

Overall Coefficient of Heat Transmission

$$U = \frac{H}{A \times T_m} = \frac{425{,}000}{83.2 \times 48.5} = 105 \text{ Btu. per sq. ft. per hr. per deg. F.}$$

The above figures are for purposes of illustration only and do not refer to any particular apparatus. Calculations are by slide rule.

For the water bath type of exchanger with firing units in operation while sludge is recirculated, computations for determination of U would be similar except that hot water inlet and outlet temperatures would both be the same as per Fig. 5 and would comprise the average temperature of the water bath on the sludge tube side during the test run. This average temperature would have to be obtained by averaging temperatures of the top and bottom of the water bath on the sludge tube side. Another method of testing would be to turn off the firing unit and determine drop in temperature of water bath for measured addition of heat to sludge. The determination and expression of "fuel to sludge" efficiency would be of considerable interest in connection with the water bath unit.

Designing engineers are urged to provide for metering and pressure measurement facilities and properly located thermometers in their designs so that the obtaining of operating data will be facilitated and thus data will be provided for future designs and for study to improve plant performance and save heating dollars.

Acknowledgement

The writer wishes to express his appreciation to Paul Cerny of the Pacific Flush Tank Co. and W. A. Darby of the Dorr Co. for their courtesy in providing photographs and data for the equipment described.

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PRESSURE IN POUNDS PER SQUARE INCH FOR DIFFERENT HEADS OF WATER

Head In Feet	0	1	2	3	4	5	6	7	8	9
0	....	.43	.87	1.30	1.73	2.16	2.60	3.03	3.46	3.90
10	4.33	4.76	5.20	5.63	6.06	6.50	6.93	7.36	7.79	8.23
20	8.66	9.09	9.53	9.96	10.39	10.83	11.26	11.69	12.12	12.56
30	12.99	13.42	13.86	14.29	14.72	15.16	15.59	16.02	16.45	16.89
40	17.32	17.75	18.19	18.62	19.05	19.49	19.92	20.35	20.78	21.22
50	21.65	22.08	22.52	22.95	23.38	23.82	24.25	24.68	25.11	25.55
60	25.98	26.41	26.85	27.28	27.71	28.15	28.58	29.01	29.44	29.88
70	30.31	30.74	31.18	31.61	32.04	32.48	32.91	33.34	33.77	34.21
80	34.64	35.07	35.51	35.94	36.37	36.81	37.24	37.67	38.10	38.54
90	38.97	39.40	39.84	40.27	40.70	41.14	41.57	42.00	42.44	42.87
100	43.30	43.74	44.17	44.60	45.03	45.47	45.90	46.33	46.77	47.20
110	47.63	48.07	48.50	48.93	49.36	49.80	50.23	50.66	51.10	51.53
120	51.96	52.40	52.83	53.26	53.69	54.13	54.56	54.99	55.43	55.86
130	56.29	56.73	57.16	57.59	58.02	58.46	58.89	59.32	59.76	60.20
140	60.62	61.06	61.49	61.92	62.35	62.79	63.22	63.65	64.09	64.52
150	64.95	65.39	65.82	66.25	66.69	67.12	67.55	67.98	68.42	68.85
160	69.28	69.72	70.15	70.58	71.02	71.45	71.88	72.31	72.75	73.18
170	73.61	74.05	74.48	74.91	75.35	75.78	76.21	76.64	77.08	77.51
180	77.94	78.38	78.81	79.24	79.68	80.11	80.54	80.97	81.41	81.84
190	82.27	82.71	83.14	83.57	84.01	84.43	84.87	85.30	85.74	86.17
200	86.60	87.04	87.47	87.90	88.33	88.77	89.20	89.63	90.07	90.50

VELOCITY IN PIPES

Rate of Flow in Gals. per Min.	NOMINAL DIAMETER OF PIPE														Rate of Flow in Gals. per Min.
	½"	¾"	1"	1¼"	1½"	2"	2½"	3"	4"	5"	6"				
	(Velocity in Feet Per Second)														
1	5.60	3.08	1.67	1.05											1
2		6.16	3.35	2.10	1.20	1.12									2
3			5.02	3.16	1.80	1.49									3
4			6.70	4.21	2.41	1.86	0.86	0.63							4
5			8.37	5.26	3.01	1.86	1.07	0.79							5
10				10.52	6.02	3.72	2.14	1.57	1.02	0.65	0.45				10
15					9.02	5.60	3.21	2.36	1.53	0.98	0.68				15
20					12.03	7.44	4.29	3.15	2.04	1.31	0.91				20
25						9.30	5.36	3.94	2.55	1.63	1.13				25
30						11.15	6.43	4.72	3.06	1.96	1.36				30
35						13.02	7.51	5.51	3.57	2.29	1.58				35
40						14.88	8.58	6.30	4.08	2.61	1.82	1.02			40
45							9.65	7.08	4.60	2.94	2.04	1.15			45
50							10.72	7.87	5.11	3.27	2.27	1.28	1.14		50
70							15.01	11.02	7.15	4.58	3.18	1.79			70
75								11.80	7.66	4.90	3.40	1.92	1.22		75
100								15.74	10.21	6.54	4.54	2.55	1.63	1.10	100
120								18.89	12.25	7.84	5.45	3.06	1.96	1.36	120
125									12.75	8.16	5.66	3.19	2.04	1.42	125
150									15.32	9.80	6.80	3.84	2.45	1.70	150
175									17.85	11.40	7.94	4.46	2.86	1.98	175
200									20.42	13.07	9.08	5.11	3.27	2.27	200
225										14.70	10.20	5.75	3.67	2.55	225
250										16.30	11.32	6.38	4.08	2.84	250
270	8"										12.25	6.90	4.41	3.06	270
275	1.60										12.50	7.03	4.49	3.12	275
300	1.73										13.62	7.66	4.90	3.40	300
325	1.76											8.94	5.72	3.98	325
350	1.92											10.21	6.54	4.54	350
400	2.24	10"										11.49	7.35	5.11	400
450	2.56														450
470	2.88	1.04										12.00	7.68	5.34	470
475	3.01	1.92	12"									12.10	7.75	5.40	475
500	3.04	1.94										12.77	8.17	5.68	500
550	3.20	2.04	1.42										8.99	6.24	550
600	3.52	2.25	1.56										9.80	6.81	600
650	3.84	2.45	1.70	14"									10.62	7.38	650
700	4.16	2.65	1.85	1.30									11.44	7.94	700
750	4.48	2.86	1.99	1.40									12.26	8.50	750
800	4.80	3.06	2.13	1.50										9.08	800
850	5.12	3.27	2.27	1.60										9.65	850
900	5.43	3.47	2.41	1.70	15"										900
950	5.76	3.67	2.56	1.80	1.67									10.20	950
1000	6.08	3.88	2.70	1.90	1.76									10.77	1000
1050	6.40	4.08	2.84	2.00	1.85									11.34	1050
1100	6.72	4.29	2.98	2.10	1.95									11.90	1100
1150	7.04	4.49	3.13	2.20	1.93	16"								12.48	1150
1200	7.36	4.70	3.27	2.30	2.02	1.99								13.05	1200
1250	7.68	4.90	3.41	2.40	2.11	2.09								13.61	1250
1300	8.00	5.41	3.55	2.50	2.20	2.09								14.20	1300
1400	8.64	6.12	4.29	3.05	2.64	3.09									1400
1500	12.00	9.10	5.68	4.00	3.52		20"								1500
2000															2000
2500		10.20	7.10	5.01	4.40	3.98		24"							2500
3000		12.24	8.52	6.01	5.28	4.78	3.07		30"						3000
3500		14.50	9.95	7.02	6.16	5.58	3.53	2.43							3500
4000			11.36	8.02	7.04	6.33	4.10	2.83	1.81						4000
4500			11.92	8.42	7.40	6.70	4.30	2.97	1.90						4500
5000			12.78	9.02	7.92	7.17	4.61	3.19	2.04		36"				5000
5500			14.20	10.22	8.80	7.96	5.12	3.54	2.26						5500
6000				11.01	9.69	8.77	5.63	3.90	2.49						6000
6500				12.00	10.56	9.56	6.14	4.25	2.72		1.57				6500
7000				13.00	11.44	10.36	6.66	4.60	2.94		2.05				7000
7500				14.02	12.32	11.16	7.16	4.97	3.17		2.21				7500
8000					13.20	11.50	7.38	5.16	3.26		2.27				8000
8500					14.00	11.96	7.68	5.32	3.40		2.37				8500
9000							8.20	5.66	3.62		2.52				9000
9500							8.70	6.02	3.85		2.68				9500
10000							9.21	6.38	4.08		2.84	42"			10000
10500							9.72	6.72	4.31		3.00				10500
11000							10.24	7.08	4.58		3.15	2.31			11000
11500								7.44	4.76		3.30	2.43			11500
12000								7.79	4.99		3.46	2.55			12000
12500								8.15	5.22		3.62	2.66			12500
13000								8.50	5.44		3.78	2.78			13000
13500								8.85	5.67		3.93	2.89			13500
13560								9.36	6.12		4.25	3.13			13560

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CHECK THESE FACTS... ON DORR CLARIFIER MAINTENANCE COSTS!

REPAIR COSTS ON DORR TYPE S (ROUND) CLARIFIERS

SIZE	PURCHASE PERIOD	YEARS IN SERVICE	NUMBER OF UNITS	REPAIR COSTS		REPAIR COST AS % OF ORIGINAL COST
				TOTAL	PER UNIT	
100'-200' Dia.	1931-42	4-15	115	$3,568	$31	0.27
Under 100' Dia.	1932-33	13-14	30	812	27	1.00
Under 100' Dia.	1934-35	11-12	65	2,121	33	0.71

A glance at the figures above will tell you exactly what repair costs can be expected with Dorr Clarifiers.

These figures are substantiated facts . . . not estimates, guesswork or wishful thinking. We believe they cannot be matched.

Repair costs are one of the primary factors upon which Clarifier excellence should be judged. Are you getting the best?

Sixteen Dorr Sifeed Clarifiers at Easterly Treatment Plant, Cleveland, Ohio, installed in 1932.

We'd like to tell you how Dorr Clarifiers stack up on performance, too. Ask a Dorr engineer for the facts.

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DORR

RESEARCH [illegible]

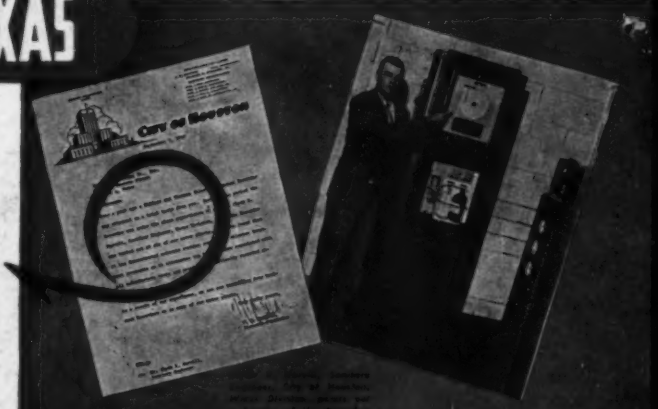
THE W&T RESIDUAL RECORDER

so good they order MORE ..

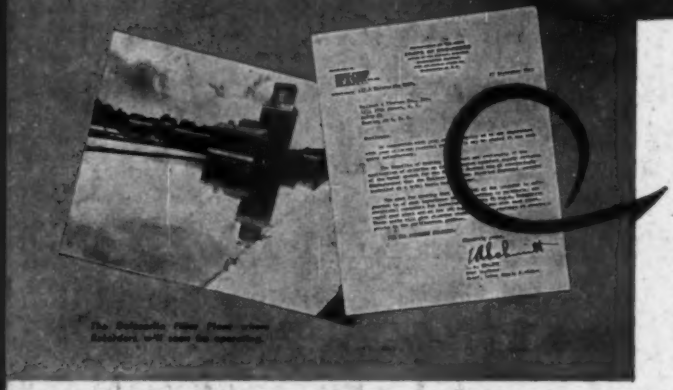
at HOUSTON, TEXAS

where a W&T Residual Recorder was installed on a trial basis and for several months put through a series of rigorous, exacting tests at six of the Houston Water Plants.

The performance of the Recorder in these tests is described by Mr. E. N. Baldwin, Director of Utilities, who writes in a recent letter "***We have found that it eliminates the inaccuracies associated with all colorimetric tests and provides automatically recorded results for permanent records. As a result of our experience, we are now installing four Residual Recorders at as many of our water plants."



at WASHINGTON, D.C.



The Dalecarlia Filter Plant where Recorders will soon be operating.

At the 85 mgd Dalecarlia Filter Plant serving the nation's capital, a W&T Residual Recorder was installed to measure the residual of the filter effluent. The results were so effective that Mr. E. A. Schmitt, Head Engineer, Chief of the Water Supply Division writes:

"***The need for knowing that the health of the consumer is safeguarded is of such importance that this office is purchasing six additional recorders for installation at its 85 mgd Dalecarlia rapid sand plant and at the 100 mgd McMillan slow sand plant. These units will give chlorine residual sample readings at strategic points in the purification process."

All the advantages of residual recording such as improved chlorine usage, better chlorination control and smoother plant operation typified by these and other installations at Cleveland, Richmond, Kansas City, and Atlanta can be obtained for your plant too. Just call your nearest W&T Representative for full details today.

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